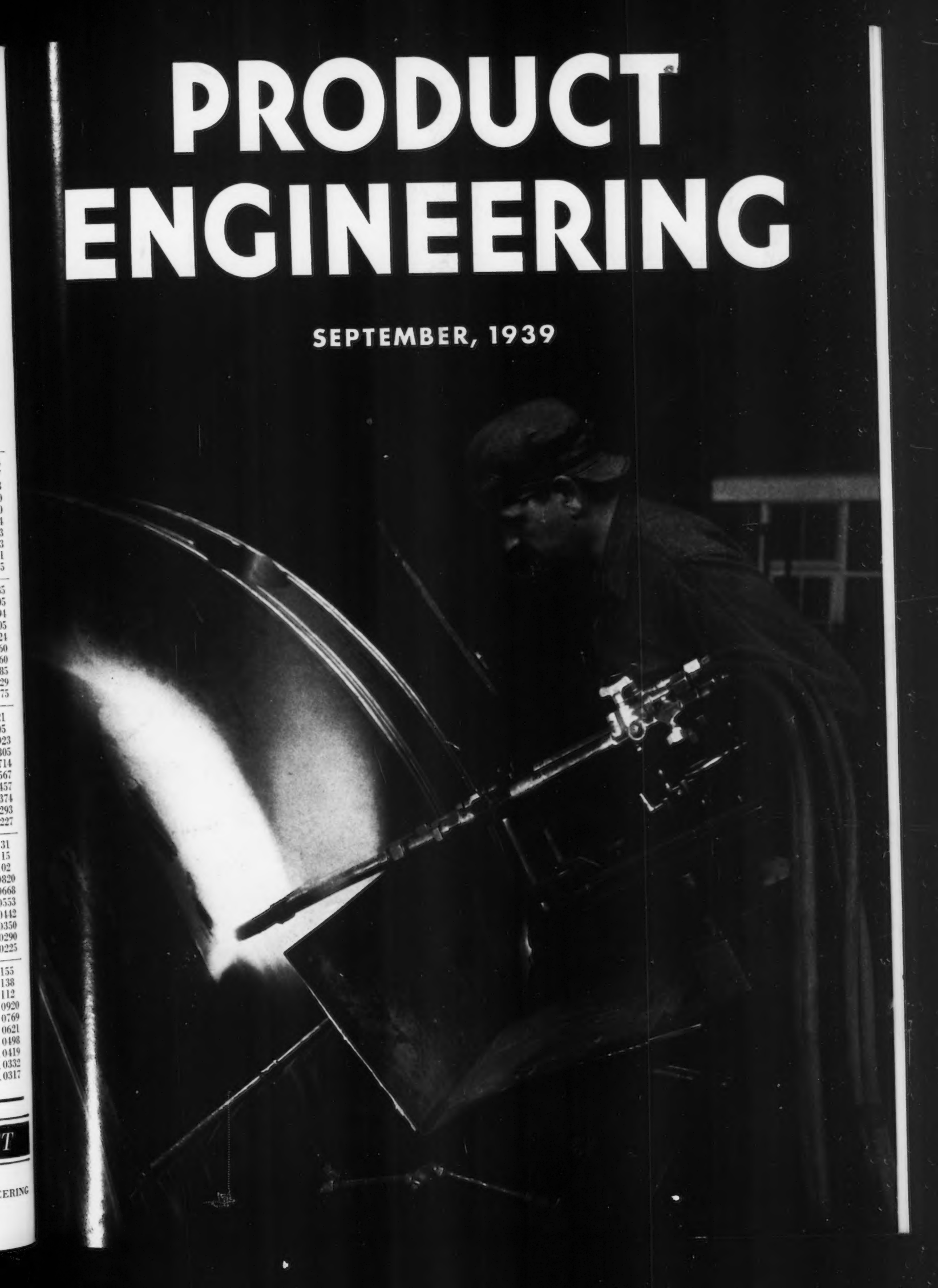
PRODUCT ENGINEERING

SEPTEMBER, 1939



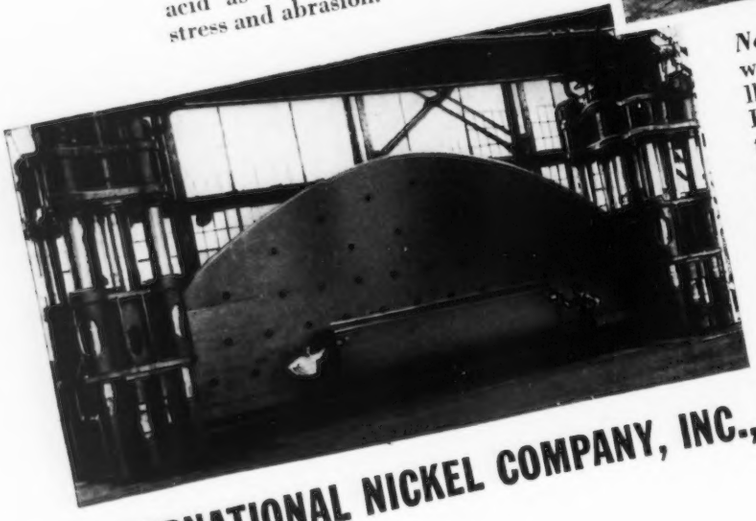
DESPITE FIRE, CHEMICALS AND STRESS...

...ECONOMICAL SATISFACTORY SERVICE RECORDS

Eight years' service instead of two was the saving to a large chemical company for specifying Nickel cast iron in this 8 ton ring. Plain iron used here corroded and eroded ½" per year. This Nickel alloyed iron wears less than ⅛" in the same time. The Straight Line Foundry and Machine Co., Syracuse, N. Y., used a 3% Nickel cast iron for these rings. Nickel induces a close-grained, pressure-tight structure which machines easily, resists corrosion and abrasion.

FROM NICKEL CAST IRONS

Sintering sulphide ores subjects cast iron grates to intense heat and to corrosive action of hot sulphur gases. Grates also suffer severe shock each cycle dropping down to discharge ore. Seeking to reduce grate costs, alternate pallets in one Dwight-Lloyd furnace were fitted with plain iron and Nickel cast iron. During this test a 4-to-1 superiority for Nickel cast iron was established! Recently new grates of Nickel-strengthened iron were ordered from Robert Mitchell, Ltd., Montreal. Nickel helps metals resist heat and acid as effectively as it minimizes stress and abrasion.



New 6,000 Ton Press! Believed to be the world's largest bending press, this 2,000,000 lb. monster was recently completed by the Baldwin-Southwark Corp., Phila. Actually twin 3,000 ton presses joined top and bottom, this huge unit easily forms 8" x 40' steel plates for the Combustion Engineering Co., Chattanooga. The 50" rams were made from a Nickel-chromium cast iron with a tensile strength of 55,000 p.s.i. Cast by the Cramp Brass and Iron Foundry, this Nickel iron, with a Brinell hardness of 250, machined easily to a fine, smooth finish. No job is too big for Nickel's help.

THE INTERNATIONAL NICKEL COMPANY, INC., 67 WALL ST., NEW YORK, N.Y.

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PRODUCT ENGINEERING

What's Coming—No show or exposition has a wider appeal, interest and value to engineering designers than the exposition of machine tools. It has been four years since the last Machine Tool Show was held in Cleveland and during the intervening time innumerable improvements have been made in the design of machine tools. Practically all of the elements that enter into the design of any kind of machinery will be found in the design of machine tools,—electric and hydraulic drives and controls, gear and belt transmissions, lubrication, bearing mountings and all kinds of power transmission units. In addition, every designer has a basic interest in machine tools because their production ability often determines design limitations. For these reasons October *P.E.* will devote more than 50 pages to detailed drawings, line diagrams, photographs and brief text setting forth important design features in the machine tools to be exhibited at the Machine Tool Show to be held October 3–14, in Cleveland.

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Cover Picture — Flame hardening — the method for obtaining localized hardening, as applied to a large lathe spool. Photo courtesy of Westinghouse Electric & Manufacturing Company and Air Reduction Sales Company.

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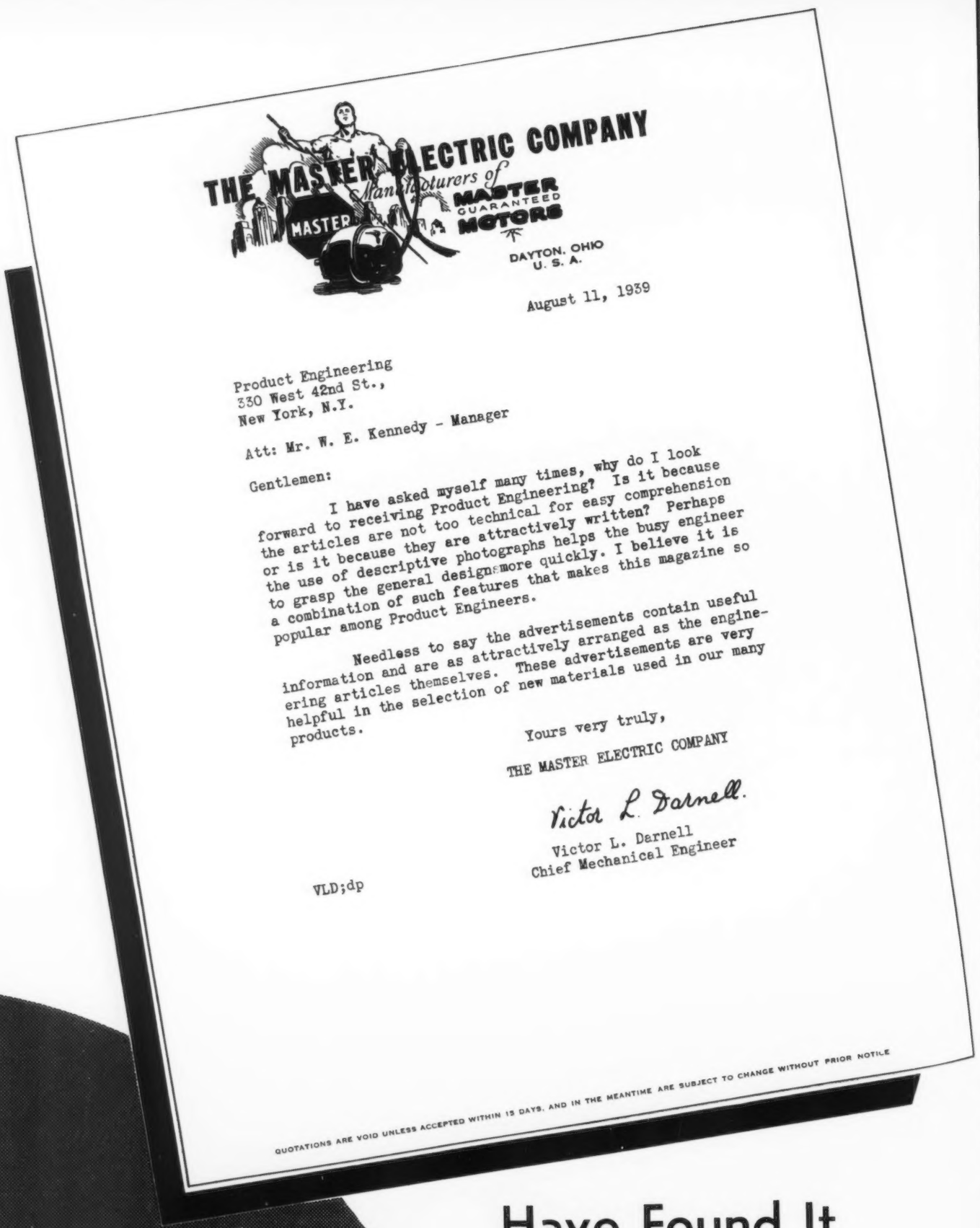

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U. S. A.

August 11, 1939

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PRODUCT ENGINEERING

GEORGE F. NORDENHOLT, *Editor*

By All The Laws of Common Sense

IF A MACHINE part with a hole in it fractures across the hole, common sense dictates that the part should be made thicker or the hole omitted. But a closer analysis of the problem might show that the necessary strength can be obtained by putting more holes in the piece. Of course a hollow shaft can easily be designed to be half again as strong as a solid shaft and if it should break common sense would dictate that the outer diameter of the hollow shaft should be increased. But the fact is, if the hollow shaft had broken because of shock loads the correct solution would be to use a solid shaft.

Because the sap of milk weed is so similar to the sap of the rubber tree, common sense showed that if the right process were developed it would be possible to make rubber out of the sap of milk weed. And certainly any man with common sense would not dare suggest that the way to make "artificial rubber" would be to make it out of coal, limestone and water.

If we go back into history we will find innumerable things that ran counter to common sense. The announcements that the earth is round, that the earth rotates about the sun, that germs cause disease, that steamships could be operated more economically than sailing ships, all met with derisive comments and active opposition. By all the laws of common sense these things just could not be, said the wise men.

Common sense plays common tricks. If one stops to analyze "common sense" it is nothing more than preconceived notions and convictions that cannot be substantiated by facts and figures. Often conclusions that are based on "common sense" are forced upon us by our prejudices.

Research has been defined as, "Proving untrue the things that common sense tells us are true, and vice versa." This is not a good definition for research, but the findings of research often do run counter to common sense. In short, "common sense" is often wrong.

Sublime faith in common sense is perhaps the greatest impediment to the progress of the works of man in the many spheres of his activity. It is equally effective as the instigator of destructive enterprise and as the throttler of progress. Scarcity means higher prices; therefore artificially restrict production to gain prosperity. Increased payrolls mean greater purchasing power; therefore dole out money, lots of it, to bring back prosperity. The fact that neither of these two objectives were accomplished by the means used has not yet shaken the "common sense" faith of many.

Every day engineers are faced with suggestions that run counter to common sense. It is a high tribute to the profession that they do so many things that are contrary to "common sense." If they didn't, expensive stainless steel would not be used as a structural material, precious metals would still be useless, domestic refrigerators would still be a novelty and radios would still cost $400 each. And the powers of ignorance would still prevail. But engineers have learned that there are many ways of doing things and the full possibilities of a new design can only be established by a complete analysis, by making researches and tests and by replacing suppositions with facts. The true philosophy of engineering sticks to the axiom that by all the laws of common sense it is only the facts that finally count.

ALUMINUM PRESSINGS

Relative Costs, Alloys Available and Design Features

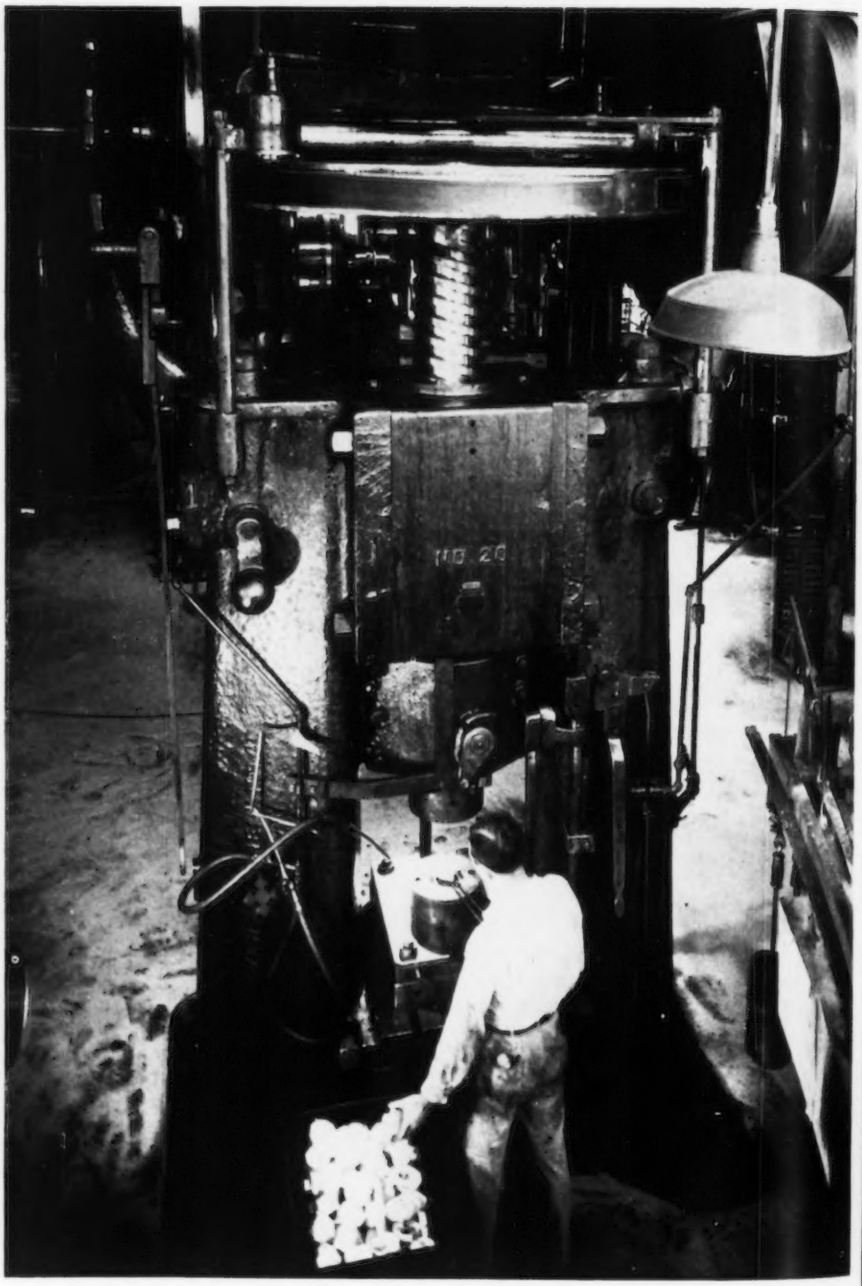
WHEREAS in the forging process the metal in the extruded or rolled bar is formed to shape by repeated blows that force the metal to fill the die cavity, in the pressing process the metal is die-formed to shape by a gradually applied pressure. Generally, the finished pressing is produced from the blank or slug by only one stroke of the press, although in complicated or large pressings it is sometimes necessary to use two or more dies to make the part, a corresponding number of pressing operations being required.

If the part is relatively small, symmetrical in shape and its pressing requires relatively little metal flow horizontally, that is, in planes perpendicular to the direction of the applied pressure, the pressing is usually done cold, at normal room temperatures. But cold pressings cannot be made if considerable horizontal flow of metal is required, which would require correspondingly high pressure.

Mechanical properties required of the part are also a determining factor as to whether a hot pressing or a cold pressing is to be used. If the finished part must be hard, must have a high yield strength, high tensile strength and high shearing strength, which can be obtained only from an alloy with high yield strength in the annealed state, it is usually necessary to produce the part by hot pressing, at a temperature above that of recrystallization or annealing.

Summarizing, the capacity of the press available and the strength of the steels available for making the dies will determine the maximum total pressure that can be applied for the pressing operation. The cross-sectional area of the part being produced will determine, for a given total pressure, the unit pressure or stress produced in the metal. The stress produced must exceed the yield point strength of the material before plastic flow begins. Yield point decreases with increased temperature, as shown in Table I. Therefore, for a given capacity press and a specific aluminum alloy, it is possible to produce a larger part as a hot pressing than as a cold pressing.

The common alloys of aluminum, 2S and 3S, like copper base alloys such as brass or bronze, develop increased mechanical properties by cold working. The tempers vary from annealed, O, to hard H, with intermediate tempers of ¼ H, ½ H and ¾ H. Heat-treatable alloys such as 11S, 14S, 17S, A51S and 53S develop somewhat increased mechanical properties by cold working but they depend chiefly upon heat-treatment for the development of their maximum mechanical properties.



Cold pressing aluminum parts in a 500-ton screw press. Presses of this type are sometimes used for hot as well as for cold pressing

As shown in Table I, 2SO aluminum will be the easiest to cold press, 3SO, A51SO, 53SO and 11SO aluminum alloys following in the order named. In Table II are given the physical properties of aluminum alloys that can be forged or hot pressed. Of this group of alloys only 2S, 3S, 11S, A51S and 53S can be cold pressed.

Alloys 2S and 3S are common alloys in that they are not heat-treatable. They are the most ductile alloys at room temperature and at forging temperature. Is-

yield strength being the least. 2SO requires the least cold-pressing pressure of any of the alloys listed. However, the machinability and mechanical properties of 2SO are the lowest of any alloy in the group, with 3SO following a close second. It follows therefore that although the material cost of these alloys is relatively low, and although they are the easiest to cold press, they are used only for parts which require a small amount of machining and which need not possess high hardness or high strength to meet service requirements.

Alloy 11S is heat-treatable and is the easiest alloy to machine. It is accordingly used to make parts which require considerable machining after the pressing operation. This alloy is usually hot pressed but can be cold pressed into smaller parts.

Alloy 14S is heat-treatable, has the highest mechanical properties of any alloy in the group, and has good machinability. It is hot pressed.

Alloy A51S is heat-treated, has good mechanical properties, and is excelled by only 11S in machinability. Alloy 17S is hot pressed.

Alloy A-51S is heat-treatable, has good machinability, nearly as good as 17S, and excellent mechanical properties. Since this alloy, in the soft temper, A51SO, has a yield strength of 7,000 lb. per sq. in., it is the easiest of heat-treatable alloys to cold press.

Alloy 53S is heat-treatable, has mechanical properties somewhat lower than A51S, machines about the same and cold presses as easily as A51S, but has the best resistance to general corrosion of any heat-treatable aluminum alloy. This alloy is used extensively in the brewery and chemical industries, as it is unaffected by beer or ale and in turn has no effect on them.

Sometimes parts made from one of the heat-treatable alloys such as 11S, 17S, or A51S are not heat-treated after pressing. In this state the temper is called "as pressed." The heat-treatable alloys in this temper have better machinability than either 2S and 3S. By furnishing parts in this temper, it is thus possible to get reasonably good machinability without the expense of heat treating.

ADVANTAGES OF HOT PRESSINGS. Although this article deals primarily with "cold pressing," and the limitations of this method of production, it should be stated that hot pressings can be made from any wrought-aluminum alloy and into complicated shapes. The hot-pressing process is considerably more versatile than cold pressing.

THIS ARTICLE was prepared by the engineers of the Scovill Manufacturing Company's Aluminum Products Division. All alloy and temper designations appearing in this article are those of the Aluminum Company of America. The tables of mechanical properties of aluminum alloys are taken from the booklet "Alcoa Aluminum and Its Alloys," issued by the Aluminum Company of America.

ADVANTAGES OF COLD PRESSINGS. For parts that are of reasonably simple design, cold pressing is usually more economical than hot, for these reasons:

1. Greater Production Rate

(a) Easy handling of cold blanks results in faster press production

(b) No delays in press operation for temperature checking

2. Lower Equipment Charges

(a) No furnace and auxiliary equipment required

3. Less Maintenance of Dies

(a) Aluminum oxide, a film which is exceptionally hard, forms faster and thicker on a hot pressing than on a cold pressing.

4. Better Machinability

(a) A part cold pressed from a given alloy will usually have better machinability than if it were hot pressed from the same alloy without subsequent heat-treatment

(b) In some instances, where a part can be cold pressed from a heat-treatable alloy, it is not necessary to heat-treat in order to secure satisfactory machinability. Thus heat-treating costs are saved

5. Cheaper to Clean

The heavier, darker film of aluminum oxide on hot pressings is more expensive to remove.

Large or complicated pieces and parts of high-strength aluminum alloys are pressed hot

Small pieces made of aluminum alloys of relatively lower yield strength are pressed cold which is usually a more economical process

FIELDS FOR ALUMINUM PRESSINGS AND FORGINGS. Where greater strength is desired than can be obtained in castings, and where it is not commercially feasible to fabricate the article from sheet or rod aluminum, pressings or forgings may be used for such parts.

Mechanical properties of some aluminum alloys for forgings or pressings are shown in Table II and for a few aluminum die-casting alloys in Table III. Even though the forging alloys have a higher yield strength and tensile strength than the die-casting alloy, they have several times greater elongation. This means that the pressings are tougher and have a higher resistance to impact.

If a part can be made from sheet—

that is, so designed that the metal thicknesses of all sections of the part are approximately the same—or from rod so that the part can be turned on an automatic screw machine, it is usually cheaper to produce the part by those methods rather than to make it as a pressing or a forging. This is primarily because of the higher speed of production on automatic equipment. It is often possible to make as one forging or one pressing a part which will replace a combination of two or more sheet or screw machine products, in which case the pressing or forging may be more economical.

If a part meets all the requirements when made as a casting, either sand cast, cast in a permanent mold, or a die-casting, a change to a forging or a pressing is not usually feasible, as the forging or pressing will be higher in price.

Frequently forgings and pressings will justify their slightly higher first cost in many ways, such as:

(a) Lower machining cost because of close tolerances and dimensional accuracy, hence less scrap

(b) Lower finishing cost because of smooth surfaces and dense structure

(c) Reduced operating costs because of lighter weight

(d) Maximum strength with minimum weight

(e) Dependability, because of uniform metallurgical and mechanical properties, which is especially important in parts responsible for the functional operation of equipment

Where light weight is desirable, especially in reducing "dead" weight in the transportation field and on portable equipment and tools, aluminum forgings or pressings offer many desirable features. The aircraft accessory and instrument field is a natural one for aluminum alloy pressings, because of their high weight-strength ratio and good corrosion resistance. A few possible applications include parts for oil filters, compasses, carburetors, ignition switches, radios, telephones, tachometers, lighting fixtures, pulleys, shock absorbers, starters and similar parts.

In the field of portable equipment and tools, applications include carpenter tools, surveying instruments, cameras, thermometers, pyrometers, microscopes, field glasses, binoculars, parts for bicycles, mechanical pencils, luggage hardware, medals, guns, fishing reels, paint and lacquer spray guns.

Aluminum forgings and pressings offer distinct advantages where the deep rich metallic sheen and the wide variety of colors, which can be furnished with aluminum "Indurited" surfaces, anodized aluminum finish, are an asset. A few possible applications include hardware and trim for use in and on automobiles, aircraft, Pullman and dining cars, refrigerators, stoves, radios, electrical appliances and lighting fixtures

Where high corrosion resistance is necessary, aluminum pressings can be used successfully in contact with

(a) Sulphur

(b) Sulphur gases, such as flue gases, natural gas, manufactured gas, sulphur dioxide, and hydrogen sulfide

(c) Sulphur compounds, such as crude oil, fuel oil, lubricating oil, gasoline, rubber and molded rubber products

(d) Naval stores, such as rosins, rosin oil, pine oil, and turpentine

(e) Concentrated nitric acid, concentrated acetic acid, butyric acid, and propionic acid

(f) Acetic anhydride

(g) Formaldehyde

(h) Hydrogen peroxide

(i) Glycerin

(j) Edible fats, such as lard, vegetable shortening and margarine

(k) Distilled water

(l) Gelatin and glue

(m) Milk

(n) Fruit juices

(o) Beer

In the design of any part symmetry is an important factor in order that the distance and volume of metal flow in every direction will be held to a minimum and uniform in each direction. Well-rounded corners around which it will be easy for the metal to flow will also contribute greatly not only to reducing the press pressure required but also to increasing the die life. This last is especially important in the case of hot pressings. In general, the same design precautions and requirements apply to cold or hot pressings as apply to forgings.

Table I—Relation of Yield Point to Temperature

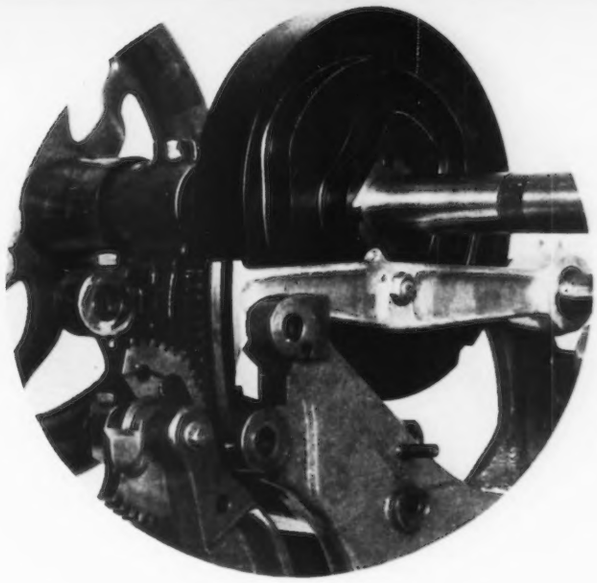
Aluminum Alloy and Temper	Typical Yield Strength — Lb. Per Sq. In.					
	75 Deg. F.	300 Deg. F.	400 Deg. F.	500 Deg. F.	600 Deg. F.	700 Deg. F.
2 SO	5,000	3,500	3,000	2,000	1,500	1,000
3 SO	6,000	5,000	4,500	3,500	2,500	2,000
11 SO	8,000	.....	.....	.....	.....	.....
53 SO	7,000	5,000	4,500	2,500	2,500	2,000
A51 SO	7,000	.....	.....	.....	.....	.....

Table II—Mechanical Properties of Aluminum Alloy Forgings

	Minimum Specification Values				Typical Values (Not Guaranteed)		
	Tension			Hardness	Shear	Fatigue	Density
Alloy	Yield Strength (Set = 0.2%) Lb. Per Sq. In.	Ultimate Strength Lb. Per Sq. In.	Elongation Per Cent in 2 Inches	Brinell 500 Kg. Load 10 mm. Ball	Shearing Strength Lb. Per Sq. In.	Endurance Limit Lb. Per Sq. In.	Lb. Per Cu. In.
11S-T	34,000	55,000	12.0	90	31,000	13,000	0.101
14S-T	50,000	65,000	10.0	130	45,000	15,000	0.101
17S-T	30,000	55,000	16.0	100	35,000	15,000	0.101
18S-T	35,000	55,000	10.0	100	.....	.....	0.103
25S-T	30,000	55,000	16.0	100	35,000	15,000	0.101
32S-T	40,000	52,000	5.0	115	38,000	14,000	0.097
A51S-T	34,000	44,000	14.0	90	32,000	10,000	0.098
53S-T	30,000	36,000	16.0	75	24,000	11,000	0.097
70S-T	40,000	50,000	16.0	85	37,000	19,000	0.107
Typical Mechanical Properties of Wrought Aluminum Alloys							
2S-H	21,000	24,000	15.0	44	13,000	8,500	0.098
3S-H	25,000	29,000	10.0	55	16,000	10,000	0.099

Table III—Typical Mechanical Properties of Aluminum Die-Casting Alloys

Alloy	Tensile Strength Lb. Per Sq. In.	Yield Strength Lb. Per Sq. In.	Elongation Per Cent in 2 In.	Endurance Limit Lb. Per Sq. In.
13	33,000	18,000	1.8	15,000
43	29,000	13,000	3.5	.....
81	32,000	24,000	1.3	16,000
82	44,000	.....	0.2	.....
83	30,000	14,000	3.5	11,500
85	35,000	19,000	2.7	15,000
93	33,000	20,000	1.0	.....



LAMINATED-PHENOLIC CAMS

Design Factors and Relative Advantages

G. J. TALBOURDET
Research Division, United Shoe Machinery Corporation

IN THE DESIGN of cams for high speed service, with the inertia loads determined and the applied load on the follower known, an approximation can be obtained of the total load exerted on the contacting surface between the cam and roll. At the crossover of the cam, when the velocity imparted to the follower is at its maximum and the acceleration changes direction, the roll leaves the cam surface and returns with an impact or a series of impacts, causing objectionable noise and vibration and excessive wear of the cam and roll surfaces. To decrease the intensity of impact, closed face cams and conjugate cams are used to limit the amount of separation between the cam and the roll.

Practical design must take into account elasticity of material and the possibility of imperfect cam and roll surfaces. These conditions are similar to those encountered in gearing. About a decade ago, experiments undertaken with non-metallic rolls gave poor results. The cause of failures could not be determined. It was not then apparent whether the cam, or the roll, should be made of non-metallic material. Three years ago, further experiments were attempted, this time with cams made of laminated phenolic materials. As hoped for, the results were satisfactory.

The properties of laminated phenolic materials which make them suitable for high speed cams are the same ones which led to their application in the field of gearing. In gear design, the influence of errors in tooth profiles, tooth spacing, and eccentricity is appreciably reduced when using laminated phenolic materials, which accounts for their successful application on high speed gears. This was definitely ascertained by Professor Earle Buckingham of the Massachusetts Institute of Technology as described in his publication "Dynamic Loads on Gear Teeth" and since then has been further substantiated in practice. The low modulus of elasticity of these materials allows greater deformation of the contacting surfaces, greater tooth deflection, lower impact loads on the gear teeth, resulting in less noise in operation.

Elasticity of Material

In the design of helical or spiral gears mounted on non-parallel shafts, the use of non-metallic materials has proved satisfactory. As early as 1930, an analysis of the nature of tooth contact made it apparent that the elasticity of the gear material has an important bearing on the resistance to wear of the tooth. With rigid bodies, gear teeth have practically point contact; with elastic materials, the size of the area contact depends upon the elastic deformation of the compressed surface. Since laminated phenolic materials have a modulus of elasticity 1/30 that of steel, elastic deformation is many times greater. On one drive where both members were case-hardened steel, the useful life was a few days only, but after replacing one steel gear with a laminated phenolic gear, no tooth wear could be detected in more than three months service. Since that time, excessive wear on spiral gear teeth has been usually eliminated by the use of non-metallic materials for one mating gear.

Laboratory tests and observations in the field have proved that the choice of mating gear material requires serious consideration. The use of bronze, aluminum, and soft steels should be avoided. Case-hardened or heat-treated steels and a good grade of cast iron give best results. Heat-treated steels, however, should have a minimum hardness of about 300 Brinell, otherwise scoring of the tooth surface may occur. Fig. 1 gives an illustration of toothwear on a soft steel gear mating with a non-metallic gear.

Nickel- or molybdenum-cast iron, heat-treated by the interrupted quench method, runs well with laminated phenolic materials. Such cast irons are effective for worms mating with non-metallic gears. Care must be taken not to reverse the materials.

Up to a few years ago, the determination of the safe load for cam surfaces was a matter of judgment and experience, since no data were available. To obtain the required information, the Research Division of the United Shoe Machinery Corporation undertook a series of tests in collaboration with Professor Buckingham who had designed and built a testing machine that determines the surface endurance limit of materials subjected to rolling or combined rolling and sliding contact such as occurs in gears, cams, and rollers. Since that time many materials have been tested, among which are laminated phenolics. While the investigation is still in progress, sufficient information has been obtained to give a

Fig. 1—Tooth wear on soft steel gear taken out of machine after mating with non-metallic gear

Fig. 2—High speed failure in laminated phenolic cam caused by internal friction—shown by blisters and darkened surface layer

good indication of the wear factors which can be used in cam and gear design.

The following simple expression derived from test results and application of the Hertz equation, can be applied to determine the safe wear load on cams.

$$W = \frac{KF}{\frac{1}{R_1} + \frac{1}{R_2}}$$

Where

W = normal safe wear load on cam surface in lb.
K = wear load factor in lb. per in. of face
F = effective width of contact in in.
R_1 = radius of cam roll in in.
R_2 = radius of curvature of cam track in in.

The radius of curvature of the cam track R_2 can be determined from an analysis of the cam motion, or a good approximation can be obtained directly from the detail drawing. Because of the cam pressure angle, the normal load on the contacting surface is greater than the resisting load on the cam roll. Therefore normal load and not resisting load on the roll should be considered.

The formula can only be applied for conditions of rolling contact. When sliding occurs, the value of wear load factor K decreases, depending upon materials, applied load, and rate of sliding. For this reason, the proportions of the roll and roll stud bearing should be carefully considered, and means should be devised to maintain rolling contact between the surfaces of cam and roll. Thus lubrication of the cam roll stud bearing is an important factor. The use of grease or semi-fluid grease on the cam track should be avoided because of its tendency to introduce a sliding action between the surfaces in contact. Light machine oil is satisfactory.

With metallic materials, the total number of repetitions and not the rapidity of the cycle determines the resistance to surface wear. Laminated phenolics, however, have large elastic deformation, high internal friction, and poor heat conductivity. Through its influence on operating temperatures the rapidity of the cycle becomes a critical factor.

Test Results

From the results of the investigation made with non-metallic materials, the following facts have been determined.

SURFACE ENDURANCE LIMITS of laminated phenolic materials vary for materials from different manufacturers. For that reason and for lack of more information, wear factors cannot be given. However, data from the investigation pursued by Professor Buckingham will be made available in the future. For an idea of the value of the wear factor, at a speed of 650 r.p.m., the safe wear load factor, K, is approximately 1,300 lb. for the best non-metallic material tested to date.

UNLIKE METALS, speed affects the surface endurance limit of phenolic materials. The greater the speed, the smaller their endurance limits as shown in Fig. 2. Some laminated phenolics are superior to others because of variation in the elastic deformation, internal friction, and heat conductivity.

FAILURE AT HIGH SPEEDS is mainly the result of excessive internal heat of friction in the material and generally causes the appearance of blisters or a darkened surface layer.

AT LOWER SPEEDS, the internal heat of friction is not the cause of failure, but surface wear occurs solely because of excessive stresses set up in the material.

SURFACE WEAR RESISTANCE of laminated phenolic materials compares favorably with that of good cast iron.

From the results of tests, experience with non-metallic gears, and studies of cam motions, it was found that laminated phenolic materials used for cams have the following advantages:

(1) Tend to absorb vibrations and deaden noise set up by contact of cam surface and mating roll. As with tooth surfaces of laminated phenolic gears, the influence of the irregularities of the cam surface is minimized.

(2) Reduce impact loads between cam and roll at crossover of cam because of the greater deformation of the cam surface during impact. Other things being equal, a laminated phenolic surface will deform many times more under compression than a steel surface.

(3) Have good resistance to surface wear, comparing favorably with a good grade of cast iron. When speed is not excessive, surface endurance limit is sometimes greater than that of cast iron.

(4) Decrease influence of inertia on cam shafts operating at variable speed and starting and stopping frequently.

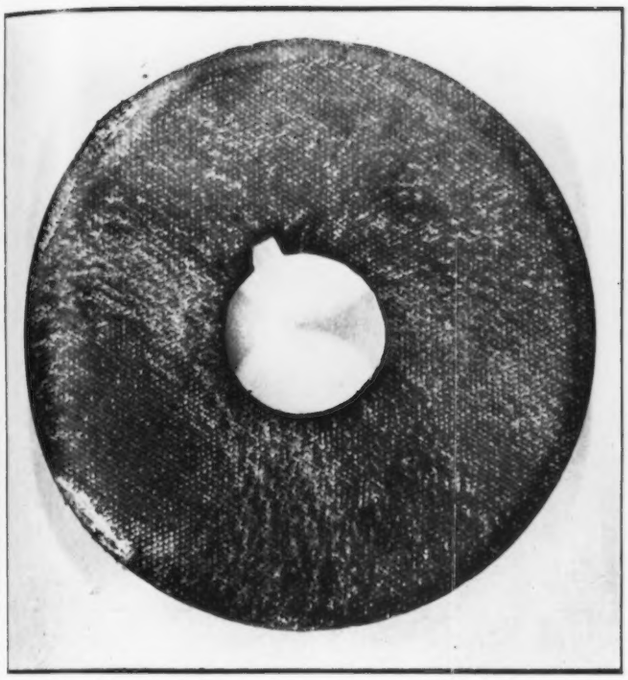


Fig. 3—Section through a cam which had failed at high speed, as indicated by the darkened surface layer

Fig. 4—Failure and breakdown of surface of a laminated phenolic cam caused by fatigue of material

Since accelerations and decelerations introduce inertia loads which result in greater stresses in the driving parts and increased loads on the supporting bearings, reduction of the rotating mass gives smoother operation and longer life.

(5) Are easily balanced. Since laminated phenolic materials are about 1/5 to 1/6 the weight of steel, balancing of cams is considerably easier.

(6) Can be molded and thus reduce machining costs. A serious objection to the use of non-metallic materials for cams is the cost of the material. In cooperation with one of the leading manufacturers, cam molding has been attempted and has proved to be successful. Machining costs are reduced enough almost to offset the greater cost of material.

Effect of Graphite

In using phenolics for cams, it has been found that those containing five to seven per cent of graphite are most suitable. When operating at low speed, the presence of graphite insures lubrication. At high speed, continuous lubrication is necessary as a cooling medium. Graphitized laminated phenolic materials also develop less internal heat, making them superior for high speed requirements.

As with gears, the choice of the mating material is important. The use of bronze, aluminum, and soft steel for rolls should be avoided. Hardened steels and heat-treated cast iron are to be preferred. Here again, surface finish and accurate machining of cam and roll are important. Care must also be taken to have sufficient material between the surface of the track and the hub; otherwise surface failure will occur.

A phenomenon which merits some consideration is the aging process taking place in laminated phenolic materials. Tests show that the limits of surface endurance increased with time, but so far the exact relation has not been determined. It is hoped that more knowledge on this subject will be available.

Some change in the size and form takes place during a certain period after the molding operation; this has been observed in the closing of the track in closed face cams. The amount of this change and the length of time of aging have not yet been completely established. Recently it was found that, following a suitable heat-treatment of the molded parts, the dimensional changes in the material are only in the order of a few thousandths of an inch. For example, with an 8 in. diam. disk, the reduction in diameter was only 0.0015 in. at the end of a week following the heat-treatment.

It would be well for the designer to remember, however, that the choice of the proper material is not always the solution to cam problems. Correct design is still a most important factor.

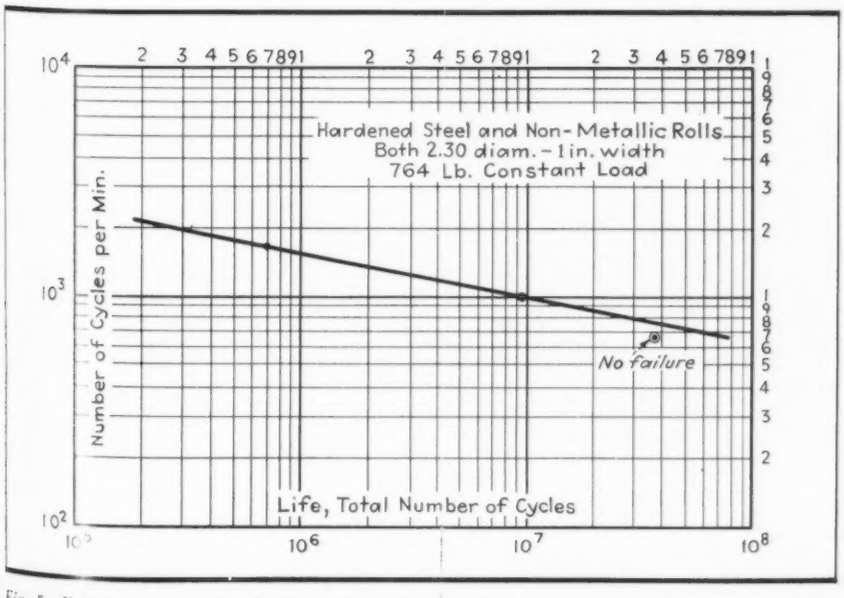
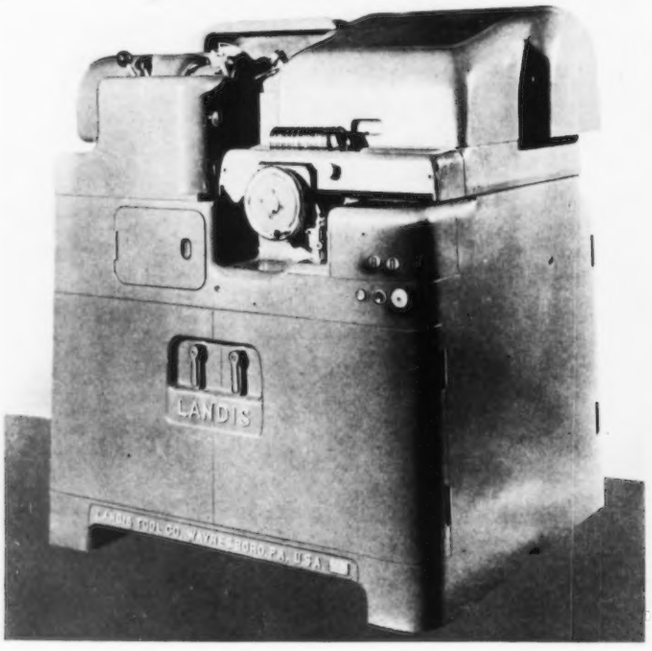
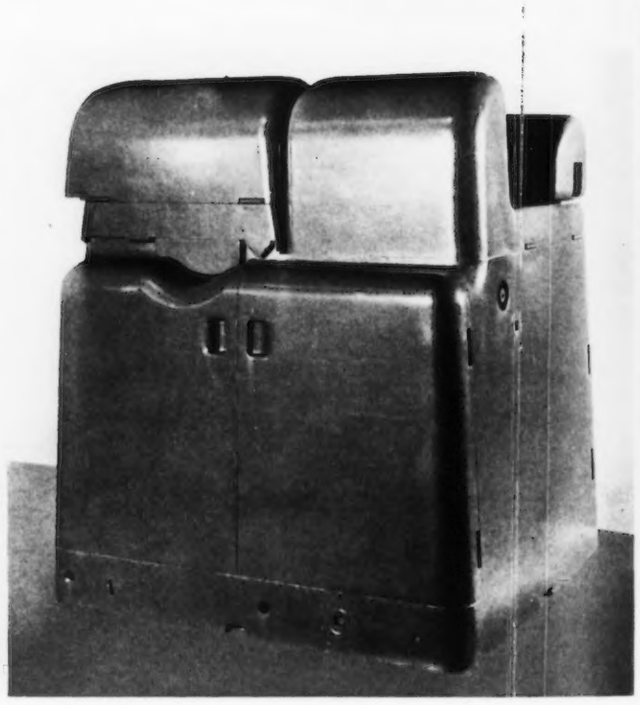


Fig. 5—Endurance test for laminated phenolic cam materials, plotted logarithmically, showing relation of endurance limit and speed

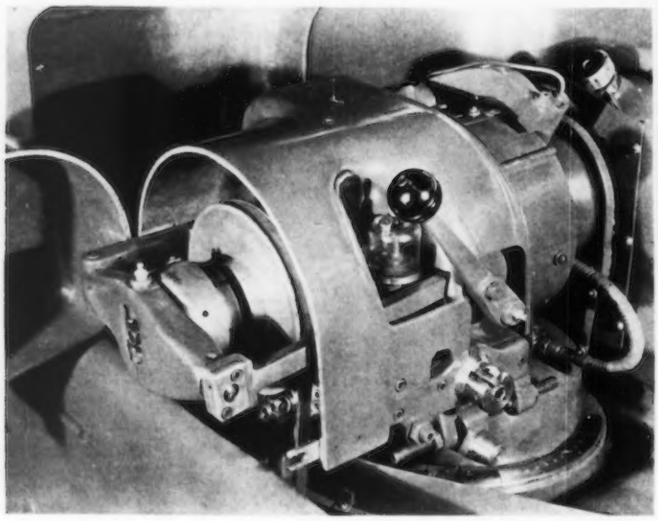
Modern Designs

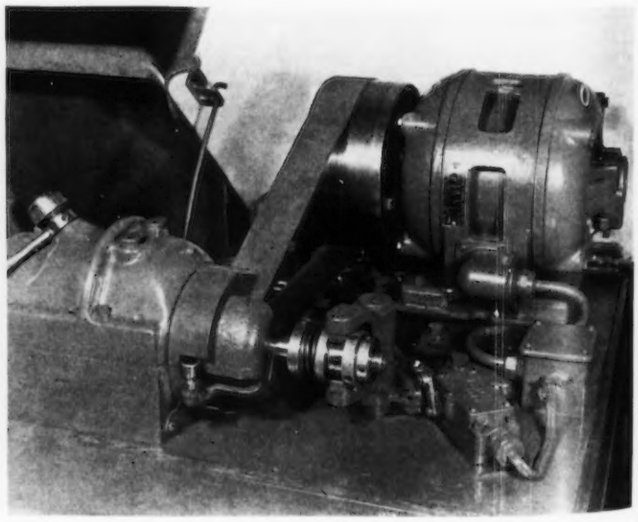
Landis Ball Bearing Race Grinder



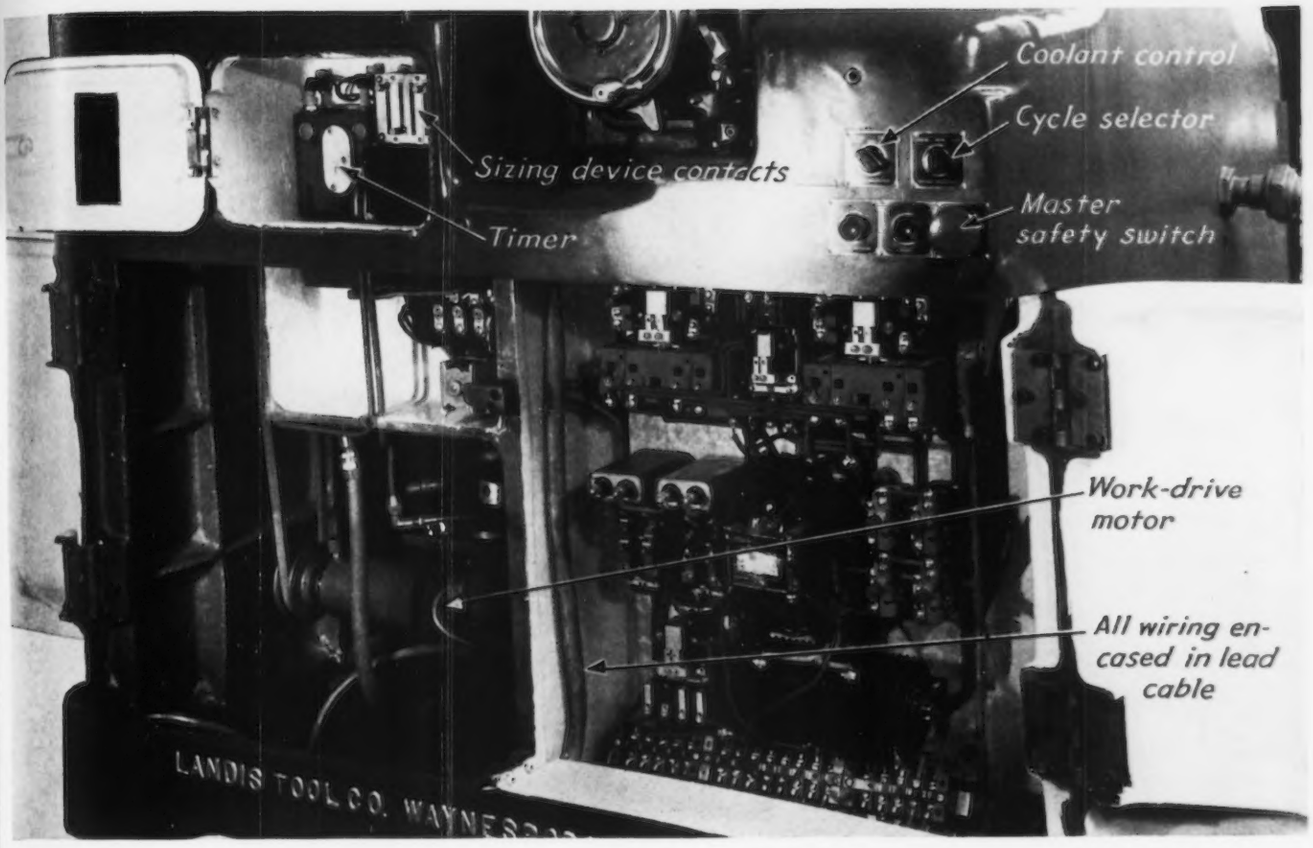


Representing a departure from the conventional grinding machine in appearance, the new Landis Tool Race-A-Way grinder has all mechanisms, control relays and motors, except wheel-drive motor, housed in compartments in the bed. Elements are accessible through large doors, front and rear, fitted with concealed hinges. Machine movements are controlled by pushbuttons and selector switches interlocked with a hydraulic circuit. Work is sized automatically by a Landis-Solex sizing device operating in combination with an electric timer. See wiring diagram, next page.

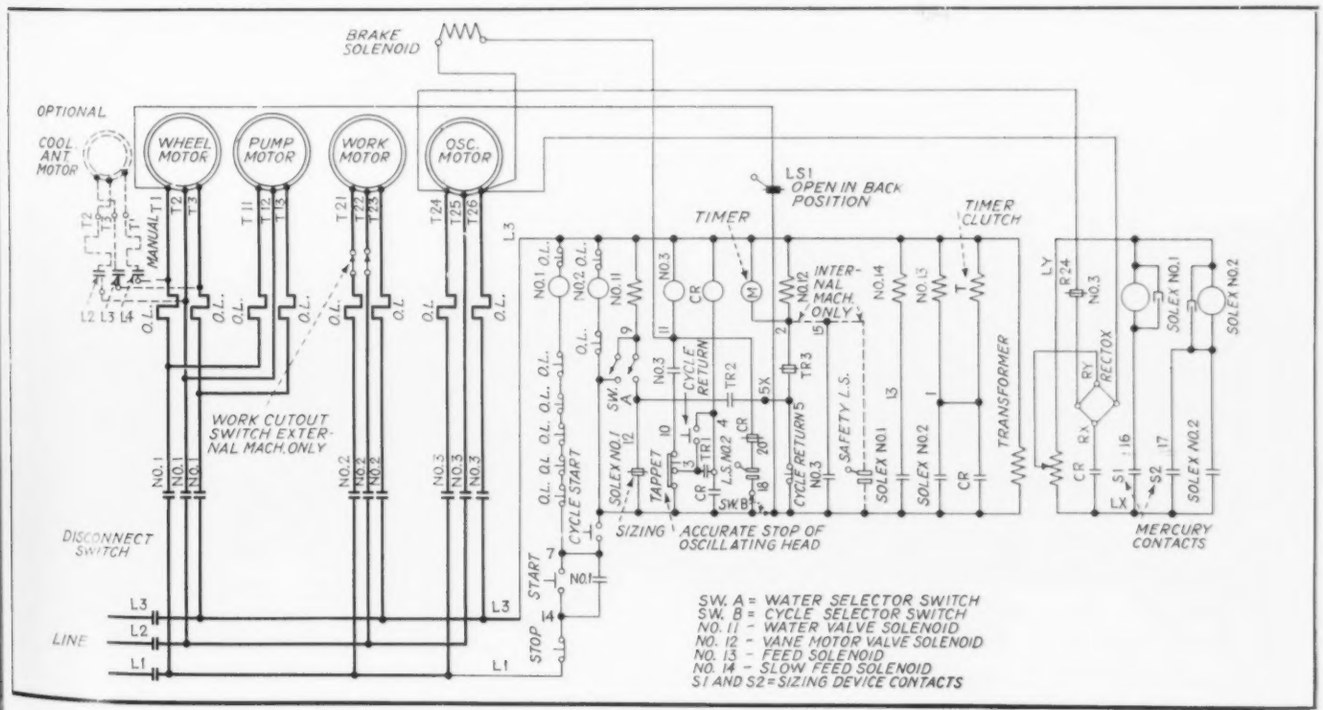




Oscillating head is mounted on preloaded ball bearings rigidly supported in the bed. Oscillating movement is obtained by an adjustable crank driven by a constant-speed ½ hp. motor. Four oscillating speeds are available through cone pulleys and worm gear reduction unit. Work spindle is driven by a constant-speed ½ hp. motor. Wheel-base, shown at the right arranged for internal grinding, is moved in and out of position by a hydraulically-actuated crank motion.



Pumps, filters, hydraulic equipment are housed in the compartment at rear of the machine. Hydraulic mechanism which moves the wheel base in and out of grinding position consists of a combination of crank and cam with a paddle type hydraulic motor lying between the two and actuating both. Crank motion moves the wheel base, while cam motion moves the wheel slide, giving pure harmonic motion and rapid, smooth acceleration and deceleration.

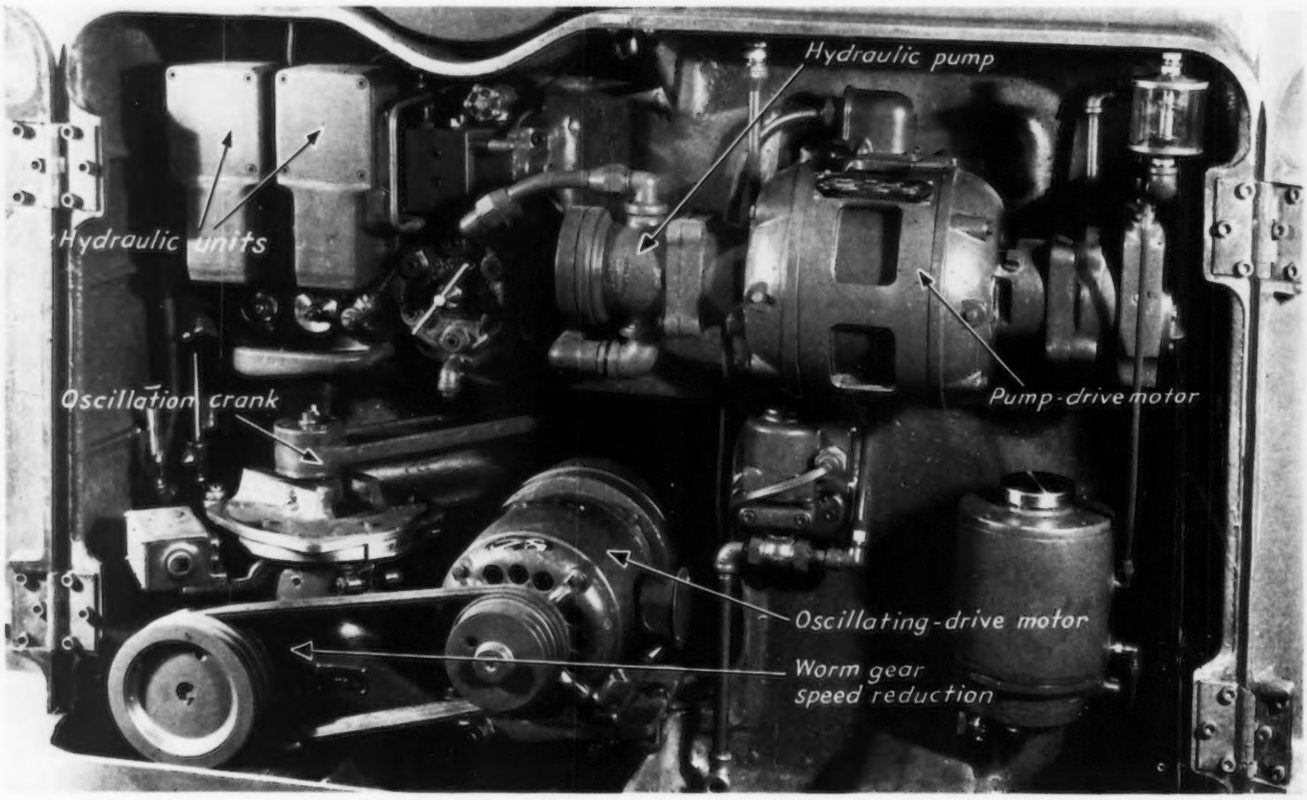


Schematic control circuit. At start, wheel base feeds in rapidly, cross movement of the wheel slide brings wheel inside of size, work head oscillation and work spindle rotation start and the sizing device moves into operative position. When work is practically to size slow-feed stops and work-head oscillation stops with head centered. Sizing device controlling these two operations sets timer in operation and for a fixed, brief time the wheel sparks out until work is down to exact size, wheel base moves to starting position, work rotation stops.

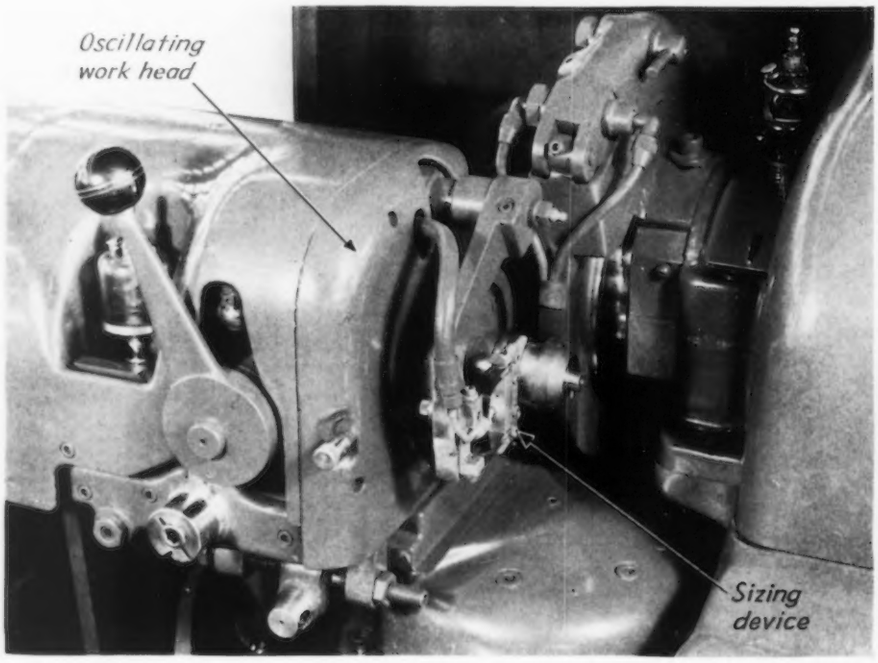
Additional details on next page.

Modern Designs—Automatically-Controlled Grinder

Continued from preceding pages



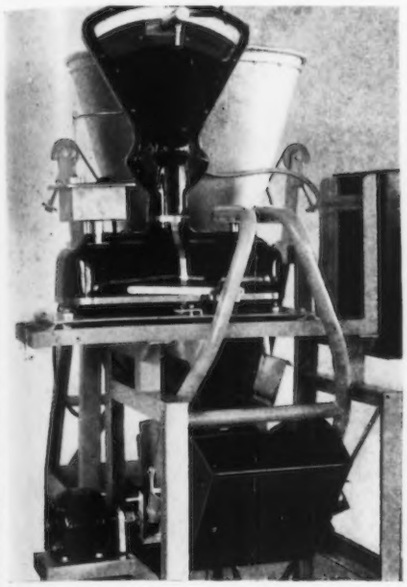
Front compartments with doors swung open showing electrical contactors and control mechanisms, timer-Solex control unit and V-belt drive to work spindle. When control panel doors are opened, the entire electric circuit is killed. All wires are in lead or synthetic rubber cables to insure freedom from trouble caused by oil deterioration. The machine is furnished with complete electrical equipment and shipped entirely wired and ready for operation.

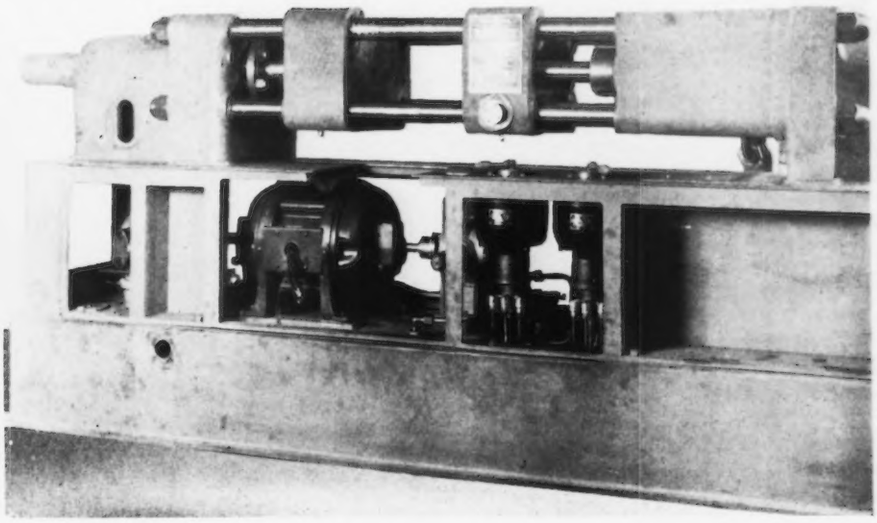


Sizing device operates on the principle that if air escapes from a pressure line, pressure in the line is affected by the size and shape of escape outlet. This pressure variation changes the level in a mercury tube and closes contacts, constituting in effect a mercury switch controlling the various feeds. On the external machine shown, the air gap is controlled by a diamond-tipped plunger which rides against the work between two carboloy shoes.

Coolant unit, used when there is no centralized coolant system, consists of a water reservoir and vertical pump with an individual driving motor. A magnetically-operated valve controls coolant flow regardless of system used

Motors Replace Solenoids



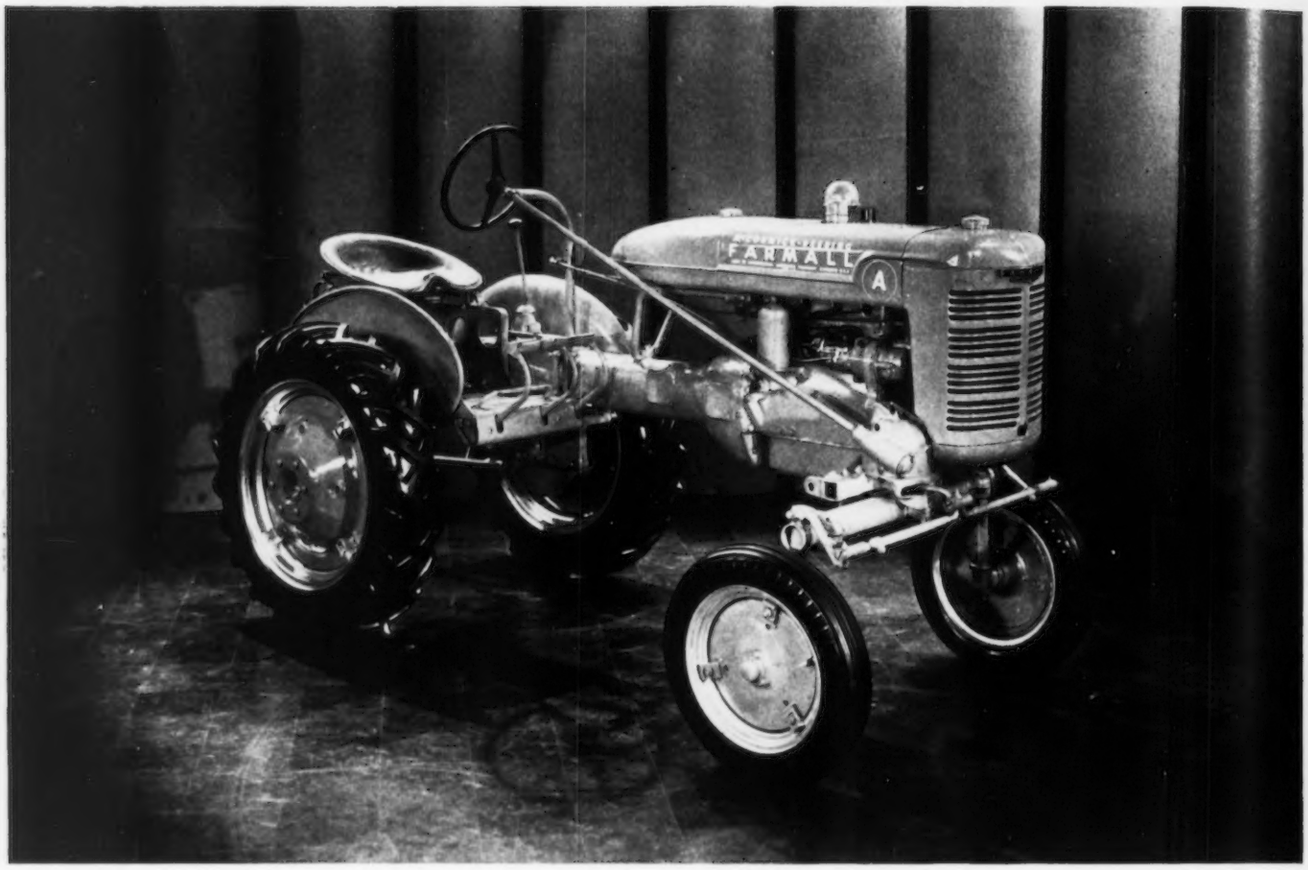


Torque motors that perform duties ordinarily done by solenoids or by hydraulic cylinders in applications in which power must be exerted to a standstill. In the Syntron weighing machine at the left, an Ohio torque motor rotates the batch-receiving hopper until it empties and a new section is positioned for the next batch. The motor must be stalled across-the-line until the next batch is weighed. In the Hydro-Power Systems' press above, two vertically-mounted Ohio torque motors operate pilot valves that control main hydraulic valves; motors stall three times per minute. Torque motors can be wound for 1, 2 or 3 phase a.c. or for d.c. Can be used to release brakes, operate valves, clamp machine members.

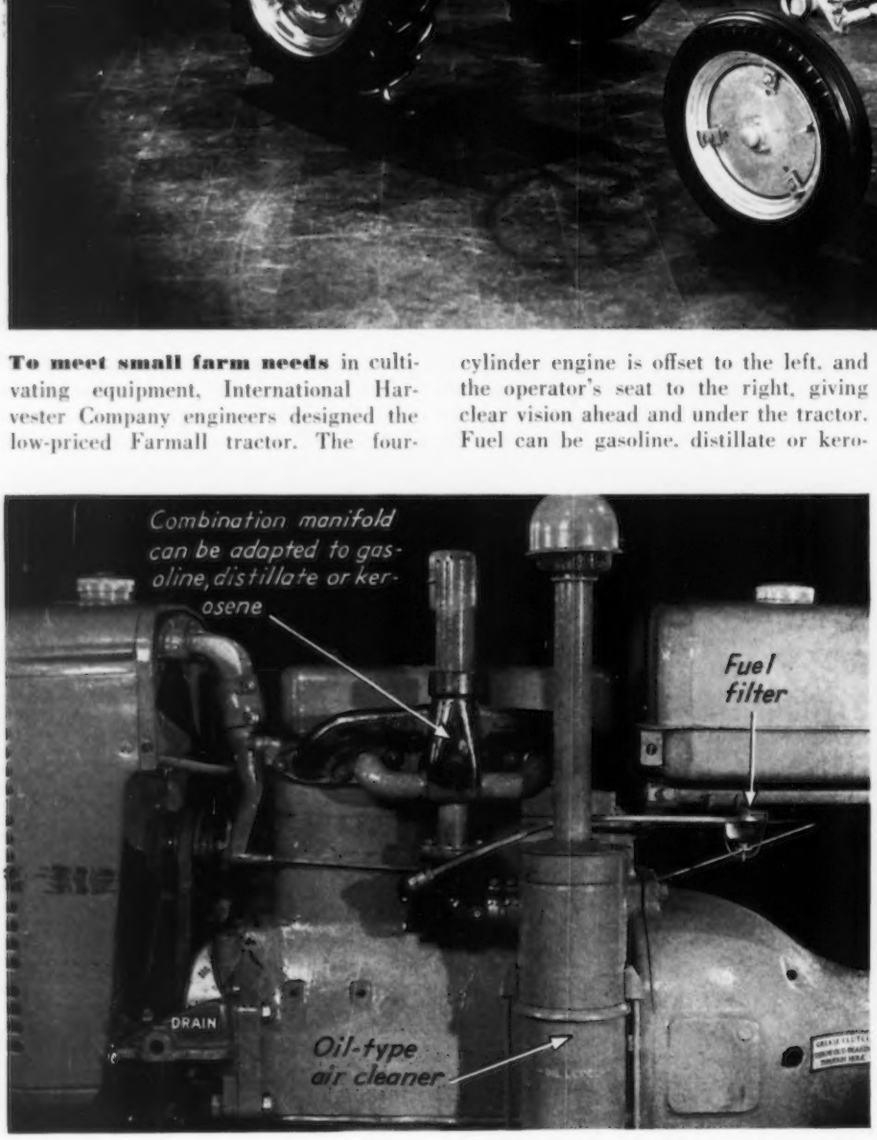
Providing protection against stains and boil-overs, Armco 18-8 stainless steel tops and back-guards are being made for the first time in regular production for the 1939 line of Eagle Foundry Company domestic ranges.

Compact precision testing machine developed by the Taber Instrument Company, for measuring resistance to rubbing abrasion, is powered by a special geared-head motor. Clutch permits manual rotation of specimen holder while observations are made. Two separate fan systems are used: one cools the motor and the other impinges on specimen holder. Air intake is at the rear. Cast aluminum base is finished in black, baked wrinkle enamel.

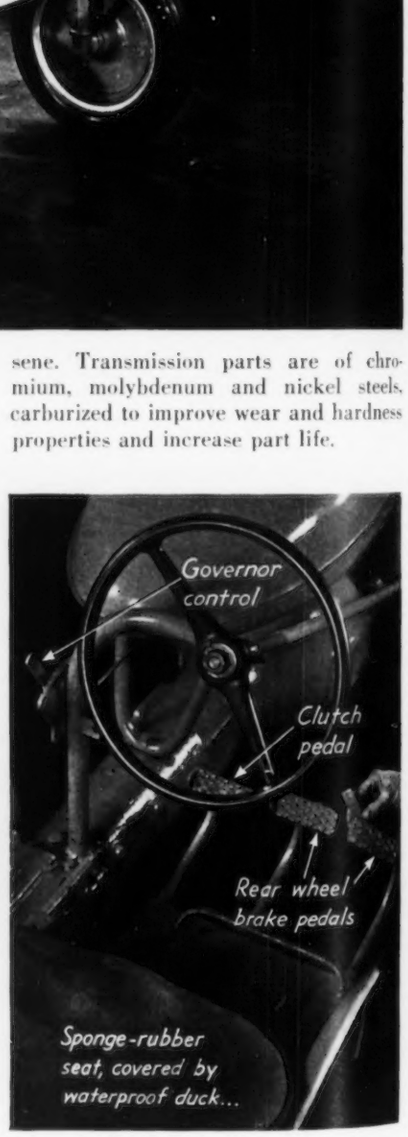
Modern Designs—Offset Engine Improves Cultivating Visibility



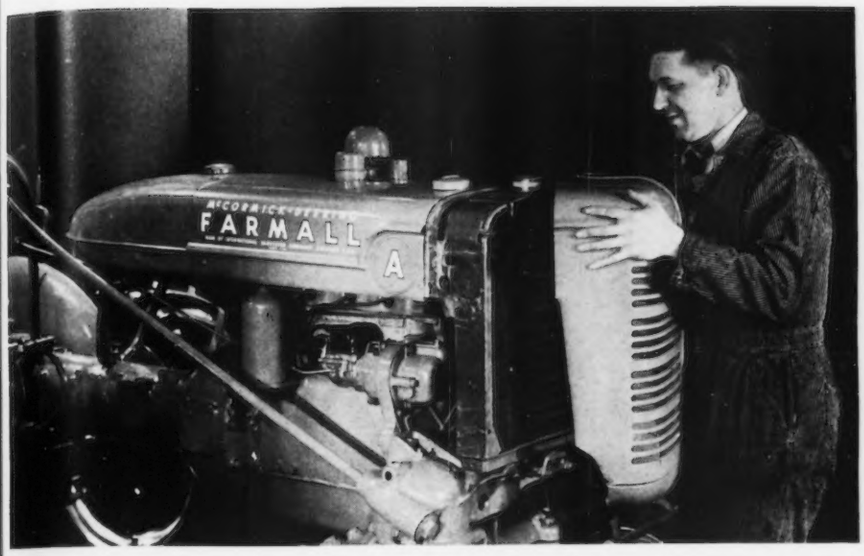
To meet small farm needs in cultivating equipment, International Harvester Company engineers designed the low-priced Farmall tractor. The four-cylinder engine is offset to the left, and the operator's seat to the right, giving clear vision ahead and under the tractor. Fuel can be gasoline, distillate or kerosene. Transmission parts are of chromium, molybdenum and nickel steels, carburized to improve wear and hardness properties and increase part life.



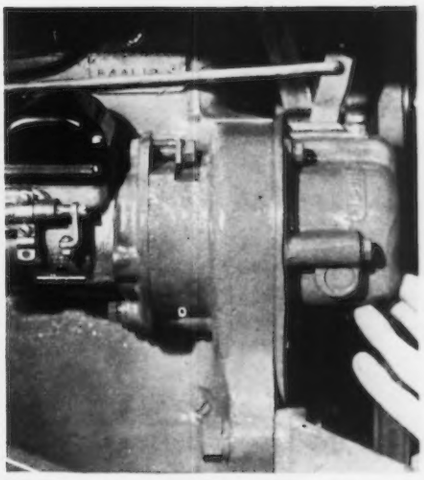
Engine has removable cylinder liners and removable valve guides. Engine has 3-in. bore, 4-in. stroke, operates at normal governed speed of 1400 r.p.m., has full pressure lubrication. Tractor has four speeds forward ranging from 2¼ to 10 mi. per hr.; 2⅞ mi. per hr. reverse speed is available.



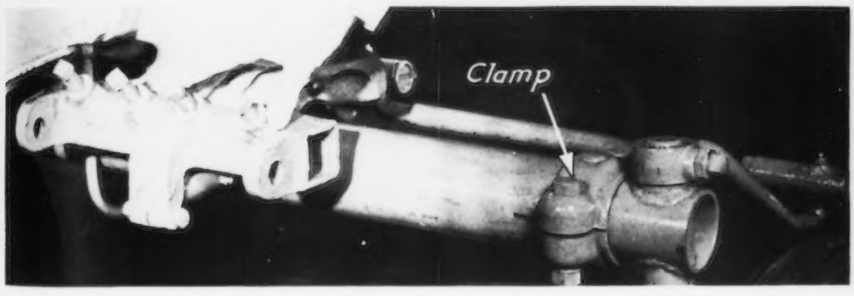
Throttle lever arrangement and steering gear support. Independent rear brakes can be locked together with latch for simultaneous operation.



Front shell and engine cover are easily removed by unscrewing four screws. Non-reversible steering mechanism consists of worm and sector-type gears mounted on ball bearings. The mechanism is sealed in an oil-tight gear case.

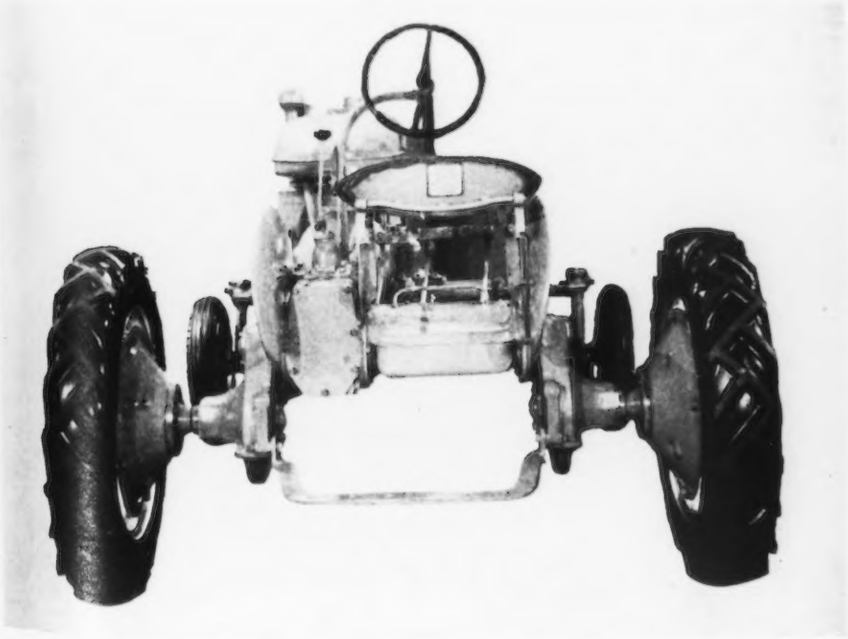


Variable-speed governor makes full throttle available at any engine speed between 900 and 1400 r.p.m., thus tractor operates at slow speeds without loss of pulling power. Control is at driver's seat.

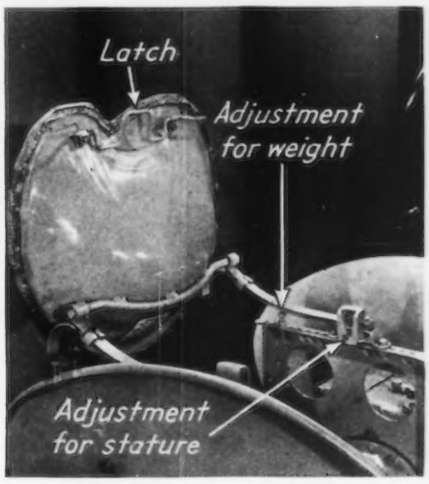


Telescoping front axle, extra equipment, permits adjustment of front wheel-gage for various widths of rows to be cultivated. Clamp on tube has a pin that fits into holes in the smaller inside tube and holds axle rigidly in place in the various extended positions. Hitch for cultivator attachment is also shown.

Oil filter of the absorption type has a replaceable element. Crankcase oil can be used for 120 hr. between changes.



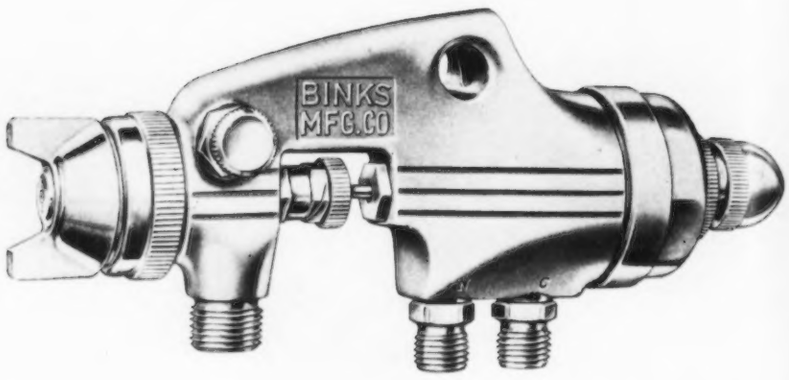
Rear wheels are adjustable to 40, 44, 48, 52, 56, 60, 64 and 68 in. wheel treads, making the tractor adaptable to a wide variety of row spacings. To obtain various gages dished hub can be mounted in any one of two positions, wheel can be mounted on hub in one of two positions, and wheels can be reversed.

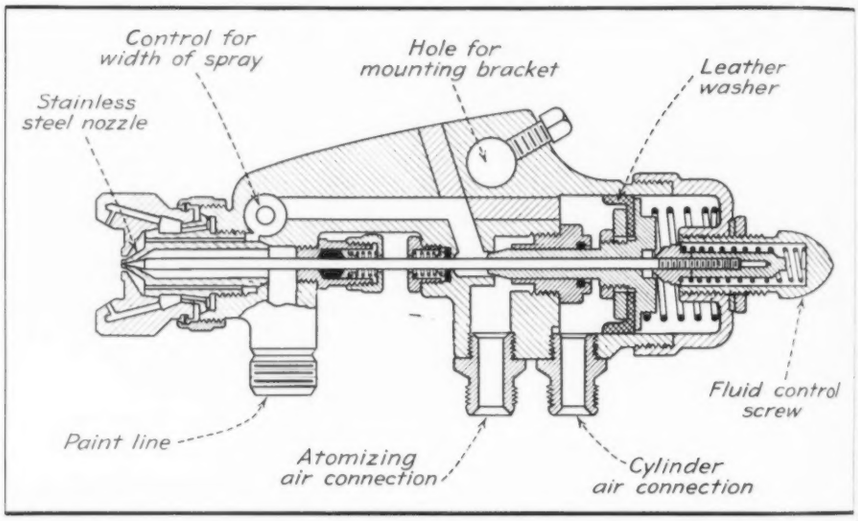


Sponge-rubber seat, duck-covered, is adjustable for weight and height of operator. It can be tilted up out of the way for standing operation of tractor.

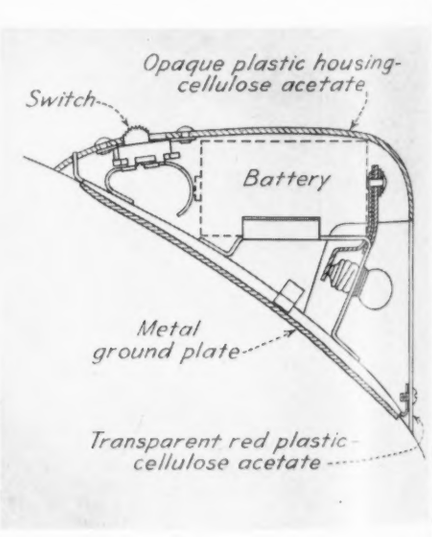
Modern Designs

Pumping unit. of the Moineau type, consists of a helical-contoured stainless steel rotor that rolls inside a helical-contoured rubber stator, creating positive pumping action. Polished line shaft has chrome bearing surfaces running in fluted rubber bearings. Known as the Peerless Hi-Lift, this pump will lift 50 gal. per min. 200 ft. at 1760 r.p.m. using a single pumping unit.





Streamlined, automatic spray gun has a plunger, actuated by an independent air supply, which opens and closes needle valve that controls spray. Quick positive action prevents spitting and dripping. Gun body is drop-forged, nickel-plated bronze; nozzle is drop-forged, chrome-plated bronze; needle valve and fluid nozzle are hardened stainless steel. Needle valve stem can be adjusted for wear. Designed by Binks Manufacturing Company.



Opaque body and transparent lens of the Delta Electric Company's Guardlite are cemented together with acetone to look like one piece. This new bicycle tail-light gives 275 deg. lens visibility. Soft rubber mounting prevents rattle and insulates electrical plate from bicycle fender. Plastic parts were molded of Tenite by the Chicago Molded Products Company.

STORED ENERGY

Comparative Analysis in Terms of Weight

VERNON H. GRANT
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IN THE following analysis, an attempt is made to evaluate the various forms of stored energy in terms of weight in connection with the study of auxiliary power in airplanes. With the exception of energy obtained from well-selected upward air currents, refueling from other aircraft, oxygen for combustion, and minute amounts of absorbed radiant energy, all energy available in an airplane for propulsion and for auxiliaries must be loaded on board before takeoff, and so represents a definite weight to be carried. The use of heavy energy sources is often justified: toy airplanes are successfully powered for very short flights by rubber bands, and steel springs as is well known are used to supply the small amounts of energy required by watches and clocks.

However, suggestions often advanced involving energy storage, while possibly not completely fantastic, are still so far from the optimum designs obtainable, that a fresh start, based upon more sound concepts of relative weights, is usually necessary. It is with the latter object in mind that this comparative analysis is given. Since electricity is usually considered as the primary means for distributing auxiliary power, evaluation is made in terms of the electrical unit pounds per kilowatt-hour.

In analyzing a given load or set of loads several factors other than the weight of the energy-storing matter must be considered. Among these factors are: weight of energy-conversion equipment, efficiency of energy-conversion equipment, reversibility of operation, possibility of combining several non-simultaneous loads for operation from the same energy-conversion equipment, possibility of increasing size of existing energy-conversion equipment to handle additional loads at a smaller weight than that of adding new equipment, amount of power available safely from energy-storage medium, and amount of weight reduction of the energy-storage medium as the energy is expended.

The ultimate, as we may now consider the meaning of the word "ultimate," application of energy on an airplane may be classified as follows: (1) Mechanical: Rotation such as main propeller, gyro flywheels and propeller pitch adjustment; Translation such as landing gear retraction; (2) Electricity: radio, lighting; (3) Heat such as cooking, oil heating.

The conversion steps involved in producing energy in one of these forms from one of the sources listed in the accompanying table may be quite complex. For example, landing gear may be retracted electrically by the following process using an engine-driven generator, a motor, and necessary mechanical linkage:

1. Gasoline to heat;
2. Heat to gas expansion;
3. Gas expansion to translation;
4. Translation to rotation;
5. Rotation to electricity;
6. Electricity to rotation;
7. Rotation to translation.

In each of these steps there is involved a fixed weight of conversion equipment, roughly proportional to the rate of conversion, or power. Also, the weight of fuel is the weight taken from the table for the amount of energy divided by the overall conversion efficiency, which is often quite low.

As the time of operation of a load is decreased, the fuel weight becomes a smaller and smaller factor. The weight of conversion equipment usually predominates, except for continuous loads on long-range airplanes.

For loads of large magnitude and short duration, where the weight of energy conversion equipment is high, it is often found advantageous to eliminate some of the conversion steps by interposing a reversible-energy storage device, which can be charged over a long period. Thus, in the example given above, the first five steps can be eliminated, at least for the duration of the load, by the use of a storage battery, and the size of the energy-conversion equipment can probably be reduced accordingly. This is increasingly important as the time of operation is reduced, which indicates the necessity of using reversible-energy storage equipment capable of rapid discharge.

For a given set of conditions, only a limited range of solutions of nearly-equal merit to an auxiliary power problem is possible. The fact that different designers obtain widely varying results when confronted with similar problems of this nature generally indicates that: (a) the problem is not being attacked from a strictly engineering standpoint; (b) only a single piece of equipment under design is being considered, rather than the auxiliary power problem of the entire airplane; (c) sufficient time for complete analyses of each problem is not available; or (d) different assumptions as to operating conditions or necessary safety factors are being made.

Need for Research

The necessity for basic research on the problem of auxiliary power, and the formulation of general requirements for the guidance of designers is apparent. Considerable work along this line is now in progress, and tangible results are expected in the near future which will simplify calculations and design procedure.

These symbols will be used in formulas which are developed and included in this article

W = weight, lb.
u = unit weight of material, 0.285 lb. /cu. in. for steel
s = allowable working stress, assumed to be 6×10^3 lb. /sq. in. for steel
a = area of cross section, sq. in.
t = thickness, in.
r = radius, in.
p = pressure, lb. /sq. in.
v = volume, cu. in. unless otherwise noted
E = energy
V = velocity, peripheral

Combustion Sources of Power Non-Reversible

GASOLINE. Equivalent gasoline weight is approximately 0.18 lb. per kw. hr. Container weight usually is about 10 per cent of the gasoline weight, roughly 0.02 lb. per kw. hr.

HYDROGEN GAS. The lower heat of combustion of H_2 is 52,920 B.t.u. per lb., equivalent to 0.06 lb. per kw. hr. Assuming hydrogen to be a perfect gas, and the container sufficiently thin-walled (reasonable assumptions up to pressures of about 3,000 lb. per sq. in.), the container weight may be developed for a sphere,

The opinions expressed herein are those of the author and are not to be construed as representing the official view of the Navy Department.

which is the optimum shape from the standpoint of weight:

$$W_e = 4\,\pi\,r^2\,tu \qquad (1)$$

$$t = \frac{\pi\,r^2\,p}{2\,\pi\,rs} = \frac{pr}{2\,s} \qquad (2)$$

$$W_e = \frac{4\,\pi\,r^3\,pu}{2\,s} \qquad (3)$$

$$W_e = \frac{3\,p\,v\,u}{2\,s} \qquad (4)$$

At a given temperature $pv = K$ (5)

Accordingly, K_H may be computed at atmospheric pressure (14.6 lb. per sq.in.) for a given quantity (1 lb.) of gas (H_2) at a definite temperature (0 deg. C.), and applied to any other values of p and v, up to pressures where the error in assuming the gas to follow Equation (5) becomes too great.

$$K_H = pv = 14.6 \times \frac{1{,}728}{0.0056} = 4.5 \times 10^6 \qquad (6)$$

Substituting in (4)

$$W_e = \frac{3 \times 4.5 \times 0.284 \times 10^6}{2 \times 6 \times 10^4} = 32 \text{ lb. per lb. of } H_2 \qquad (7)$$

For 0.06 lb. of H_2

$$W_e = 1.92 \text{ lb.}$$
$$\text{Total weight} = 0.06 + 1.92 = 1.98 \text{ lb. per kw.hr.} \qquad (8)$$

The weight of a cylinder to hold this gas would be between 1⅓ to 2 times the weight given by Equation (7), depending upon the shape of the cylinder ends. Table I is based upon cylinders weighing 1½ times as much as equivalent spheres.

Liquid hydrogen. The idea of using liquid hydrogen as a fuel is not new, but storage of such material at atmospheric pressure on board aircraft presents the opportunity for interesting speculation. We may assume the hydrogen to be carried in containers similar in design to present gasoline tanks, covered with thermal insulation, of double wall construction with the space between the walls evacuated. The thermal insulation must be adequate to prevent vaporization of the liquid at a rate greater than can be utilized, or the excess will be wasted.

The heating value of hydrogen is about three times that of gasoline, by weight, but the specific gravity of liquid hydrogen is only one-tenth that of gasoline. Accordingly, the hydrogen container must have over three times the capacity of a gasoline tank holding an equivalent amount of energy. Assuming as a rough approximation, that insulation doubles the weight, the hydrogen container would weigh six times as much as an equivalent gasoline tank, or 0.12 lb. per kw. hr.

Explosive cartridge. Tests have indicated that the weight per energy content of a typical explosive powder is 2.78 lb. per kw.hr. Data on available cartridges show that the weight of fuel (powder) is approximately half the weight of the total cartridge. The table gives the container weight as equal to the fuel weight. Incidentally, explosive powder is heavier than other combustion sources partly because oxygen for combustion is included in fuel weight.

Electrochemical Sources

Dry cell battery (non-reversible). According to data obtained from tests at the National Bureau of Standards, dry cells have a unit weight varying between 45 and 65 lb. per kw.hr. depending upon size of cell and other factors.

Storage battery (reversible). An investigation of aircraft storage batteries conducted by C. B. Mirick at the Naval Research laboratory has indicated that the weight per kw. hr. output varies between 108 lb. (10 hr. rate) and 480 lb. (3 min. rate). The latter figure does not take into account the recuperative action of the battery.

Mechanical Sources, Reversible

Assuming isothermal expansion, the total amount of energy in compressed perfect gas is represented by:

$$E = 144 \times 0.434\,p_1\,v_1 \log \frac{v_2}{v_1} \text{ ft. lb.} \qquad (9)$$

(where v is in cu. ft.)

At atmospheric pressure and a temperature of 0 deg. C. 1 lb. of air occupies 12.4 cu. ft. (v_2).

Then,

$$v_1 = \frac{14.6}{p_1} \times 12.4 \qquad (10)$$

Substituting (10) in (9):

$$E = \frac{144 \times 0.434\,p_1 \times 14.6 \times 12.4}{p_1} \times \log \frac{12.4}{\frac{14.6 \times 12.4}{p_1}} \text{ ft. lb. per lb.} \qquad (11)$$

$$= 144 \times 14.6 \times 0.434 \times 12.4\,(\log p_1 - \log 14.6) \text{ ft. lb. per lb.} \qquad (12)$$

$$\frac{W}{E} = \frac{235}{\log p_1 - 1.164} \text{ lb. per kw. hr.} \qquad (13)$$

It should be noted that the energy of compressed gas must be released slowly to avoid reduction of temperature to such an extent that the gas freezes. This necessity tends to defeat the advantage of a reversible-energy source as discussed previously. Also, the use of a compressed-air energy reservoir in a hydraulic system presents the danger of explosion, particularly if petroleum oil is employed as the hydraulic medium. In the table, Equation (13) is evaluated for several values of p_1 for compressed air.

The weight of a spherical container for air may be derived by substituting values in Equation (6) and using the result in Equation (4):

$$K_A = pv = 14.6 \times \frac{1{,}728}{0.0807} = 3.12 \times 10^6 \qquad (14)$$

$$W = \frac{3 \times 0.284 \times 3.12 \times 10^6}{2 \times 6 \times 10^4} = 2.2 \text{ lb. per lb. of air} \qquad (15)$$

As stated above, a cylindrical container would be between 1 1/3 and 2 times as heavy as the ideal spherical container. Inasmuch as a cylinder or some other form is usually more adaptable to stowage in an airplane, particularly if the size is large, this difference is important.

Flywheel. The energy in the rim of

Table I—Weight-Energy Conversion Factors

Type	Weight lb. per kw.hr.	Container weight lb. per kw.hr.	Total weight lb. per kw.hr.
Gasoline	0.18	0.02	0.20
H_2 gas — sphere	0.06	1.92	1.98
H_2 gas — cylinder	0.06	2.97	3.03
H_2 liquid	0.06	0.12	0.18
Cartridge	2.78	2.78	5.56
Dry battery	45–65	....	45–65
Storage battery (10 hr.)	108	....	108
Storage battery (3 min.)	480	....	480
Compressed air (100 lb. per sq.in.)	281	600*	881
Compressed air (500 lb. per sq.in.)	204	420*	624
Compressed air (1,000 lb. per sq.in.)	128	273*	401
Compressed air (5,000 lb. per sq.in.)	93	200*	293
Flywheel (not including hub and web)	302	....	302
Rubber	1,290	....	1,290
Steel, tension or compression	147,500	....	147,500
Steel, spring	443,000	....	443,000

* Container weights based upon spheres, cylinders are 1⅓ to 2 times as heavy.

a thin-rimmed flywheel may be derived as follows:

The force F on the rim, normal to a diameter,

$$F = \frac{W V^2}{2 \pi rg} \quad (16)$$

$$s = \frac{F}{a} = \frac{W V^2}{2 \pi rga} \quad (17)$$

Now, $$W = 2 \pi rau \quad (18)$$

therefore,

$$a = \frac{2 \pi rau V^2}{2 \pi rga} = \frac{u V^2}{g} \quad (19)$$

or $$V^2 = \frac{gs}{u} \quad (20)$$

Then $$E = \frac{W V^2}{2 g} = \frac{Wgs}{2 ug} = \frac{Ws}{2 u} \quad (21)$$

$$\frac{W}{E} = \frac{2 u}{s} = \frac{2 \times 12 \times 0.284 \times 2.655 \times 10^6}{6 \times 10^3}$$

$$= 302 \text{ lb. per kw. hr.} \quad (22)$$

to this figure must be added, of course, the weight of the hub, web, and other parts, as well as a correction for finite rim thickness.

Rubber. A pound of rubber, of 1 sq. in. uniform cross-section and about 2.32 ft. long may be stretched safely according to an investigation conducted by the Goodyear Zeppelin Company about 11.6 ft. with an average modulus of elasticity of 71 lb. per original sq. in. The energy in the stretched rubber will be

$$E = \frac{5}{2} \times 11.6 \times 71 = 2{,}060 \text{ ft. lb. per lb.} \quad (23)$$

$$\frac{W}{E} = \frac{2{,}655{,}000}{2{,}060} = 1{,}290 \text{ lb. per kw. hr.} \quad (24)$$

Steel. If a pound of steel, one square inch in section and 0.293 ft. long is stressed in tension or compression to 6×10^3 lb. per sq. in., the energy stored would be

$$E = \frac{s^2 \times length}{2 \times mod.\ of\ el.} = \frac{36 \times 10^6 \times 0.293}{2 \times 29 \times 10^6}$$

$$= 18.2 \text{ ft. lb. per lb.} \quad (25)$$

$$\frac{W}{E} = \frac{2{,}655{,}000}{18} = 147{,}500 \text{ lb. per kw. hr.} \quad (26)$$

If the steel is stressed in bending, as in a spring, stress limitation permits the storage of only one-third the energy possible under uniform stress. The ratio W/E then is 443,000 lb. per kw. hour.

Heat. Difficulties involved in the storage and utilization of thermal energy make this form of energy of little value in aircraft, except for the negative application of ice or solid CO_2 for food preservation. In this application, the latent heat of fusion of the material, rather than its low temperature, furnishes most of the effect desired.

Ball Bearing Size Shafts

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Chief Engineer, Insley Manufacturing Co.

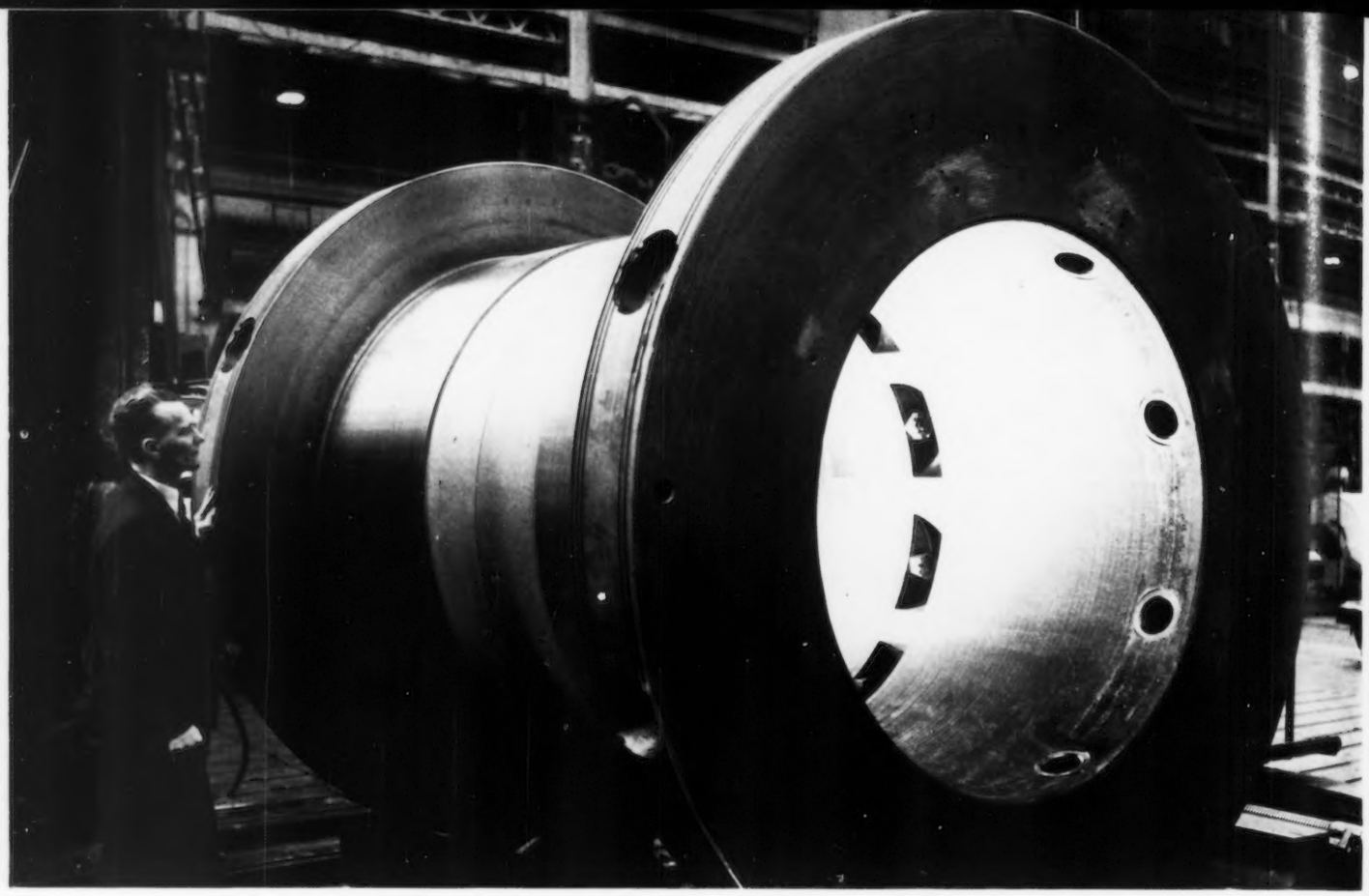
THE DATA PRESENTED in the accompanying table were calculated from

m = shaft diam. in mm.
d = shaft diam. in in.
f = 0.03937 (conversion factor 1 mm.)
C = circumference of shaft in in. = πfm
A = cross-sectional area in sq. in. = Cfm 4
S = section modulus in in.^{3} = Afm 8
I = moment of inertia in in.^{4} = Sfm 2

Metric dimensions can quickly be converted to approximate sixteenths of an inch by multiplying the dimension expressed in millimeters by the factor 0.63, thus 25 mm. × 0.63 = 15.75 sixteenths of an inch.

Properties of Ball Bearing Bore Size Shafts

Basic Bear No.	Diameter mm.	Diameter In.	Circumference In.	Area Sq. In.	Section Mod. In.^{3}	Moment of Inertia In.^{4}
Extra Small Bearings						
34	4	0.15748	0.49474	0.019478	0.00038343	0.000030192
35	5	0.19685	0.61843	0.030435	0.00074889	0.000073711
36	6	0.23622	0.74211	0.043826	0.0012941	0.00015284
37	7	0.27559	0.86580	0.059653	0.0020550	0.00028317
38	8	0.31496	0.98949	0.077913	0.0030675	0.00048307
39	9	0.35433	1.1132	0.098608	0.0043675	0.00077377
Regular Size Bearings						
00	10	0.3937	1.2368	0.12171	0.0059911	0.0011794
	11	0.43307	1.3605	0.14730	0.0079741	0.0017267
01	12	0.47244	1.4842	0.17530	0.010353	0.0024455
	13	0.51181	1.6079	0.20574	0.013162	0.0033683
	14	0.55118	1.7316	0.23861	0.016440	0.0045307
02	15	0.59055	1.8553	0.27391	0.020220	0.0059705
	16	0.62992	1.9790	0.31165	0.024540	0.0077291
03	17	0.66929	2.1027	0.35183	0.029435	0.0098503
	18	0.70866	2.2263	0.39443	0.034940	0.012380
	19	0.74803	2.3500	0.43947	0.041092	0.015369
04	20	0.7874	2.4737	0.48696	0.047929	0.018870
	21	0.82677	2.5974	0.53687	0.055484	0.022937
	22	0.86614	2.7211	0.58924	0.063793	0.027627
	23	0.90551	2.8448	0.64401	0.072895	0.033004
	24	0.94488	2.9685	0.70121	0.082821	0.039128
05	25	0.98425	3.0921	0.76087	0.093612	0.046069
06	30	1.1811	3.7106	1.0956	0.16176	0.095528
07	35	1.37795	4.3290	1.4914	0.25687	0.17698
08	40	1.57480	4.9474	1.9478	0.38343	0.30192
09	45	1.77165	5.5658	2.4652	0.54593	0.48360
10	50	1.96850	6.1843	3.0435	0.74889	0.73711
11	55	2.16535	6.8027	3.6826	0.99676	1.0792
12	60	2.3622	7.4211	4.3826	1.2941	1.5281
13	65	2.55905	8.0395	5.1434	1.6453	2.1052
14	70	2.7559	8.6580	5.9653	2.0550	2.8317
15	75	2.95275	9.2764	6.8478	2.5275	3.7316
16	80	3.1496	9.8949	7.7913	3.0675	4.8307
17	85	3.34645	10.513	8.7957	3.6793	6.1564
18	90	3.5433	11.132	9.8608	4.3675	7.7377
19	95	3.74015	11.750	10.987	5.1365	9.6057
20	100	3.937	12.368	12.174	5.9911	11.794
21	105	4.13385	12.987	13.422	6.9355	14.336
22	110	4.3307	13.605	14.730	7.9741	17.267
Extra Large Bearings						
24	120	4.7244	14.842	17.530	10.353	24.455
26	130	5.1181	16.079	20.574	13.162	33.683
28	140	5.5118	17.316	23.861	16.440	45.307
30	150	5.9055	18.553	27.391	20.220	59.705
32	160	6.2992	19.790	31.165	24.540	77.291
34	170	6.6929	21.027	35.183	29.435	98.503
36	180	7.0866	22.263	39.443	34.940	123.80
38	190	7.4803	23.500	43.947	41.092	153.69
40	200	7.874	24.737	48.696	47.929	188.70
42	210	8.2677	25.974	53.687	55.484	229.37
44	220	8.6614	27.211	58.921	63.793	276.27
46	230	9.0551	28.448	64.401	72.895	330.04



FLAME HARDENING

Applied to Large Forged Steel Lathe Spools

SURFACE HARDENING of large forged steel cylindrical parts by means of the oxy-acetylene flame process was recently accomplished by engineers of the Westinghouse Electric & Manufacturing Company. The pieces hardened were lathe driving head spools and revolving rest bearings, parts of heavy duty horizontal boring lathes built by the Niles Tool Works, a subsidiary of General Machine Corporation.

Made in two pieces with a bolted girth joint, as shown in Fig. 1, the driving head spools were centered and aligned by a male and female joint. Nuts for the bolts were inserted and tightened through pockets or recesses machined in the bore of the spools. For positioning a split spider the assembled spool was turned down at about mid length to a diameter one inch smaller than the journal bearing. The gear for driving the

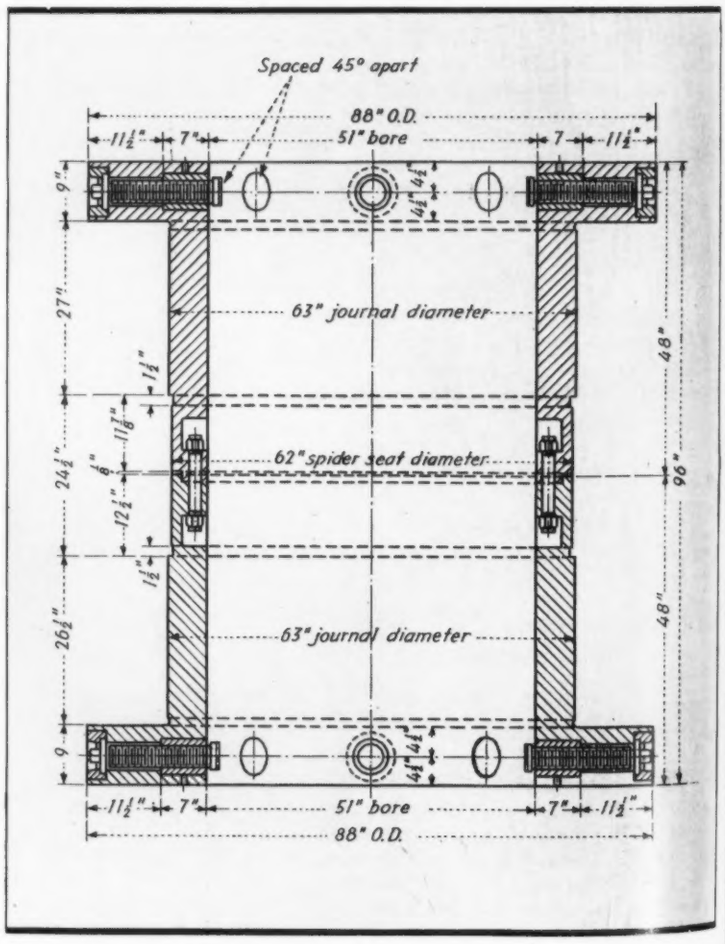


Fig. 1—Assembly details, bolting arrangement and dimensions of main drive spools for large horizontal boring lathes

head was keyed to the spider. Fig. 2 shows the parts assembled.

Principal dimensions of the assembled drive spools are shown in Fig. 1. Spool parts are S.A.E. 1040 coarse-grained forgings. The cast ingots from which the sections were forged weighed approximately 52,000 lb. The forgings were made by the Carnegie-Illinois Steel Corporation at their Homestead plant. After forging and machining the pieces weighed 22,000 lb. each approximately. The finish machining, hardening and finish grinding operations were done by Westinghouse Electric & Manufacturing Company in their East Pittsburgh shops. Oxyacetylene flame hardening as a method for hardening the surfaces of the spools could be used with least investment in plant and process equipment and was accordingly selected. The contract specifications called for pieces with bearing surfaces from 350 to 500 Brinell, with no checks and no chatter marks.

To revolve the work while hardening, the spools were mounted on a spider mandrel and placed in a large-swing lathe which had low-speed back gears. To obtain speed control the lathe was driven with a variable speed d.c. motor equipped with a rheostat.

Oxygen bottles were piped up and connected to a header in two ten-bottle sections, as shown in Fig. 5, in a way such that a ten or a twenty bottle supply could be used as needed. Heavy-duty regulators of the two-stage type each with a 3,000 cu.ft. per hr. capacity were connected to each section. Oxygen was proportioned at a control panel for each torch, a pressure regulator was also installed in each torch line. Acetylene cylinders were arranged in banks six to a torch. Each bank of cylinders had water flash-back arresters for safety, and each cylinder had a mechanical arrester in a coil. Heavy-duty regulators were placed between each bank of acetylene cylinders and the valves on the control panel for each torch. In order to obtain quick and easy positioning of the torches when in operation they were mounted on adjustable bar supports.

To secure data that could be used to determine correct procedure in regards to gas pressures and work speed that would produce the best surface, experiments were conducted using a special cylinder made from the same material that was used to make the spools. Speeds of 6, 7, 8 and 9 in. per min. were tried. It was found that the surface produced at the slow rate of 6 in. per min. was too hard, and that the fast rate of 9 in. per min. produced a surface that was too soft. The degree of hardness and quality of surface produced by the 7-in. rate approached more nearly the properties desired, and was consequently chosen as the proper rate to use for the hardening operations. With the trial cylinder it was found that by regulating the pressure of the water quench Brinells of 400 to 450 could be obtained, with the zone of hardness extending about $\frac{1}{8}$ in. below the surface.

When flame hardening the spools, the lathe was geared up and the motor rheostat adjusted so that the spool surface passed the torches at a rate of 7 in. per min. The torches were held so that the tip of the blue cone of a neutral flame was $\frac{1}{8}$ in. away from the work about 10 in. above the line of lathe centers and normal to the spool surface.

Flame temperature was approximately 6,300 deg. F. The temperature of the work under the flame was from 1,500 to 1,550 deg. F. The heated zone on the surface passed under the flame and was quenched with a water spray.

The surface produced was uniformly hard, free from pits, cracks or checks, oxide or corrosion. Brinell hardnesses produced at various surface areas are

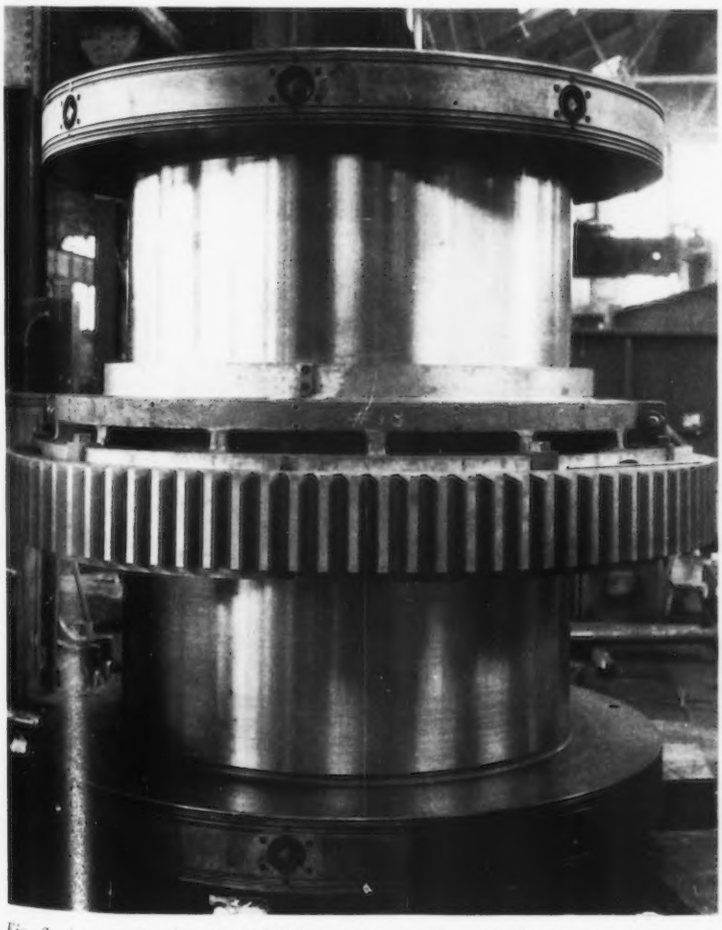


Fig. 2 Flame hardened 44,000-lb. lathe spool with drive gear keyed to split spider clamped over assembled spool

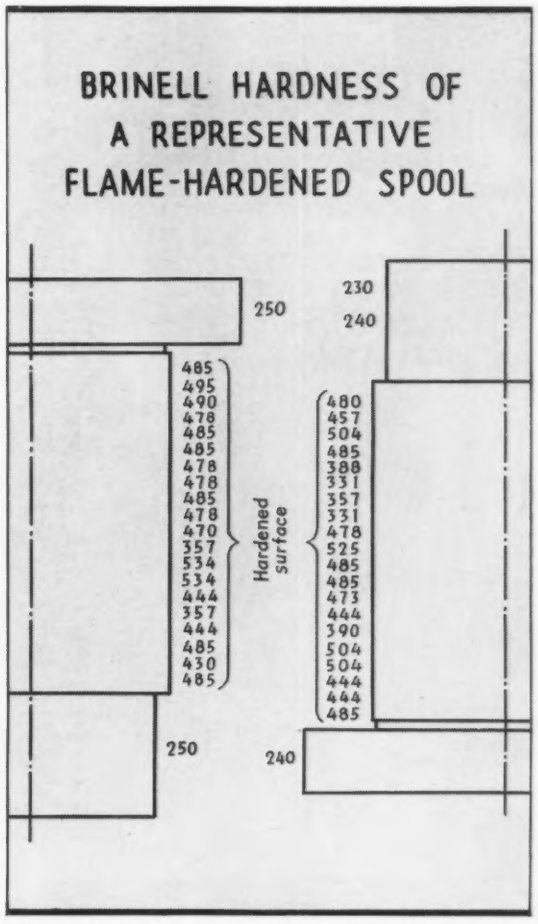


Fig. 3 Uniformity of hardness obtained on surface of driving spools is shown by Brinell numbers

indicated in Fig. 3. Tests indicated that tempering was not required, since no excessive stresses were found.

In the design of these heavy duty boring lathes there are some interesting features other than the fabrication of the forged spools and sleeves. Since these new lathes were designed for finish boring as well as for rough boring, the running clearance in the bearing had to be small, this dimension was not allowed to exceed 0.008 in. In order to accommodate the work, for which the lathes were designed, narrow driving head spools and hence narrow bearings were necessary, the ratio of bearing length to diameter being about two to five. To secure long bearing life and good alignment the hardened steel spools were supported in removable bronze bearings.

Continuous lubrication is supplied to the driving spool by means of motor driven high and low pressure pumps. Lubricating oil, S.A.E. 30, is pumped into the bearing at the low point through the opening shown in Fig. 4. To make sure that the entire surface of the journal is lubricated, oil is also fed in by gravity at points around the bearing.

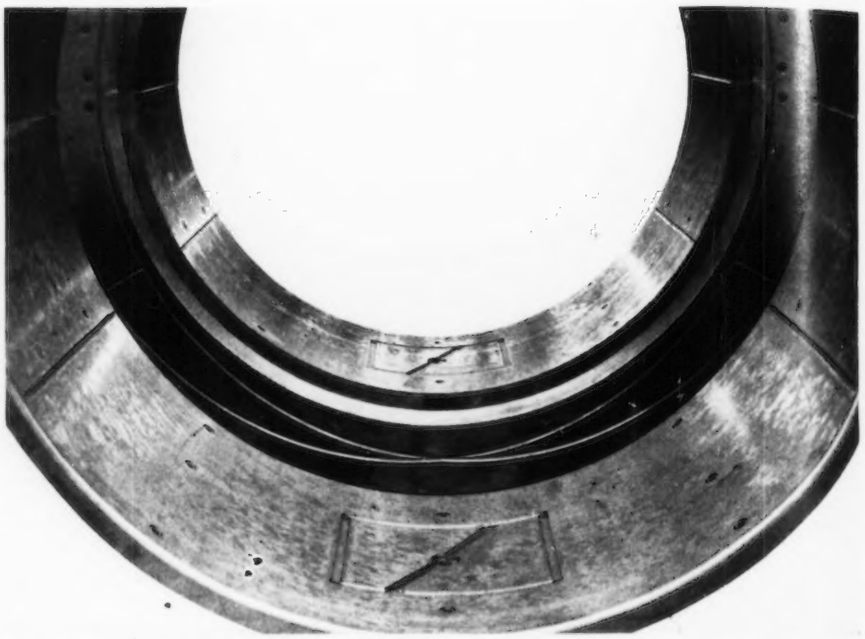
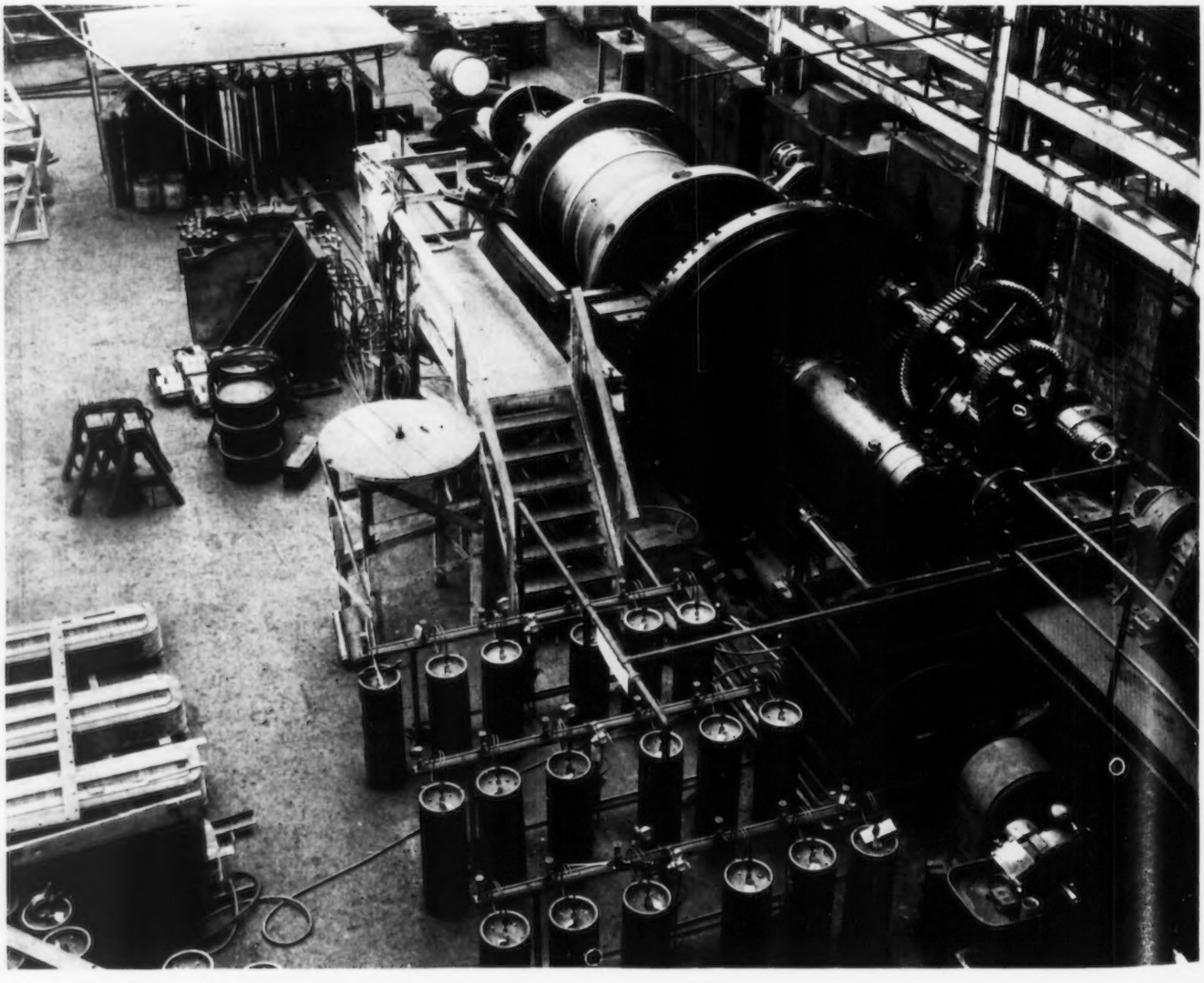


Fig. 4—View inside of bearing showing holes through which oil is forced and grooves for distributing oil over face of spool flange

Fig. 5—Arrangement of grouping and piping oxygen bottles and acetylene cylinders for flame hardening operation. Piece to be hardened is shown in the lathe



COLORING OF METALS—IV

By Chemical or Electrochemical Methods

DR. C. B. F. YOUNG
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RECENTLY a new process for coloring metals, known as "Electrocolor," was developed for commercial use by the United Chromium, Inc. (See *Product Engineering*, August, 1937, p. 317–320). All the colors that are attainable by this process, and the range includes almost every color of the spectrum, are produced in a plating bath, the composition of which is not changed or varied in any manner in order to effect any change in color, the hue produced being primarily a function of the length of time that the article remains in the plating bath. The bath is preferably a water solution containing complex copper ions, in which the article to be finished is immersed and serves as the cathode. Pure metallic copper is used as the anode and the plating deposit is cuprous oxide. The bath is operated at low voltage, the usual desirable constant voltage being approximately 0.4 volts, with a current density of approximately 0.5 amp. per sq. ft., which is also surprisingly low. The cost of the bath amounts to about 65 cents per gallon. The bath is stable and can be operated continuously.

The color obtained with the "Electrocolor" process is the result of the reflection and refraction of light passing through the semi-transparent, electro-deposited coating. As the thickness of the coating increases the color changes successively from violet to blue, green, yellow and red in cycles. This cycle of color changes is repeated as the plating builds up, but in each succeeding cycle the colors become darker. Finally, if the plating is continued long enough, the so-called "pigmentary-colors" are produced and these are of a deeper and darker shade. The length of plating time may range from one to 30 min. or more. The rate of change of color during plating is relatively slow so that it is easy to reproduce the same color on the same kind of surface merely by timing the plating operation.

Another factor that determines the final shade, color and brilliance is the character of the surface before plating. A highly polished surface gives a mirror-like finish; a scratch brushed surface gives a soft eggshell finish. Further, different colors can be obtained by preliminary plated deposits of other metals such as pure copper or nickel. In every instance the reflective brilliance of the final finish corresponds to the polish of the base surface before plating.

Stainless steel plaque, 8 in. wide by 9 in. high, in which the design is first printed on the plate and then immersed in a ferric chloride hydro-chloric acid bath to etch the background. After which the background is electroplated using black nickel. Next the relief is removed and the high lights buffed with a soft wheel

The preparation of the articles to be plated involves the usual steps common to other electrolytic plating processes for the cleaning and preparation of the original base surface.

A piece removed from the plating bath may again be inserted and the plating operation continued without interruption and with no harmful effect. A piece left in the bath beyond its scheduled time may easily be stripped and again colored. The bath operation cycles in any given color, say a green, are recurrently obtained at different time intervals, there being a slight difference in the color at each cycle. A full range of colors may be obtained in the first cycle as well as in later cycles, although, as already stated, there will be a slight difference of shades.

The great range of possibilities that are available may be indicated by pointing out that not only can the choice of color be varied to an almost unlimited degree by the actual plating operation, but it may also be further controlled and regulated by the choice of preliminary deposits of other metals such as copper or nickel. Furthermore, it may be varied by a proper choice of polishing operations on the base; an article may be either highly polished or produced with a dull finish, and the final appearance of the article varied from the brilliance of

high metallic luster to the softness of a subdued pastel shade.

Any shade and color once produced can be duplicated and matched merely by specifying the base metal, its surface finish, preliminary platings, and the length of time in the plating bath. It is solely a question of the initial surface and the length of time in the plating bath. The accuracy with which this must be measured is well within the range of careful commercial production.

Control of the composition of the plating bath, of the temperature and of the operating voltage or the current density is required. In common with other types of plating equipment provisions for taking care of these essentials can readily be made.

From the technical operating standpoint, one of the most noteworthy characteristics of the bath is its throwing power, which makes it possible to color recessed articles without any auxiliary anodes, and without any variation in the shade of color. It is possible to treat almost all of the usual base metals. Some of these, such as aluminum, may require preliminary coatings of other metals, but in general the process leaves the user free to choose whatever base metal will best satisfy his needs from the standpoint of economy, ease of finishing and strength. The range of colors is very wide and closely approximates that of the spectrum.

Variations and additional effects that can be produced by special treatment of the articles to be colored are almost unlimited. For example, two-tone effects can be produced by the simple expedient of stopping off part of the area to be colored for a portion of the time. It is also possible to obtain combinations of chromium plating and color by simply stopping off certain portions of the article prior to chromium plating and then coloring those portions directly, leaving the chromium plated area unaffected. This can easily be done by making the chromium deposit passive, so that no color is deposited.

Another method which is general in nature has been mentioned before but it will be discussed again because of its wide application. Ammonium molybdate solutions are good coloring baths for many metals. These solutions containing 20–80 grams per liter of the salt, can be used with currents of 2–10 amp. per sq. ft. The subject to be colored is made the cathode, which can be iron, steel, aluminum, cadmium, nickel, zinc or many others. The shades obtained are almost infinite in number.

The solution containing cupric sulfate, cream of tartar, and sodium carbonate can be used with a current and almost any color may be obtained. The author has been working on this type of bath for some time and hopes to publish these results soon.

The lead acetate solution can also be used for general coloring, although the lighter colors are produced easier when either copper or brass is used as the base material. However, this is easily overcome as any material may be first plated with either brass or copper and the results introduced into the bath. By varying the pH of this solution, some attractive yellows, browns, blues, and purples can be obtained.

Another rather ingenious method of coloring metals consists of first depositing silver over the base material and then dropping a solution of potassium sulfide in various places over the plate. Where the sulfide comes in contact with the silver a brown or yellow streak of silver sulfide is formed. The object is then dried and lacquered. The silver can also be buffed before the sulfide is applied. Some attractive imitation marble objects can be made from ordinary steel in this manner.

In trying out the different formulas, given in this series of articles, it must be kept in mind that they are general and must be treated as such. If results are not as indicated, the concentrations of the interacting salts, temperature, time of immersion, and other factors should be varied so as to produce the colors wanted. Many times the base metal used will have a direct bearing on the color received. All of these variables must be taken into account when certain definite colors are being sought. However, after once the color is obtained, the results can be duplicated provided all conditions remain constant throughout the experiment.

At this point it might be well to discuss more at length the coloring of stainless steel. This material is desired by many designers because of its non-corrosive character. However, there are times when colors are almost demanded. So far, the demand has not been fulfilled very well. True, several investigators have claimed to have solved the problem but judging from the commercial adaptation of these, the results have not been forthcoming.

One method which has been in use for some time is to vary the buffing and in so doing surfaces can be produced which are mirror finishes to grayish satin surfaces. Another method consists of cutting down the surface by using sand blast or its equivalent. This produces a characteristic finish which can be made in attractive designs by using stencils to protect certain areas. If steel shot is substituted for the sand, still other types of finishes are produced. Another method which is similar to the above consists of protecting certain areas with an asphalt resist and then immersing the alloy in a chemical solution which will attack the exposed surfaces. Another type of contrast is produced by rolling in certain designs. This material has been used as a prefinished product by several designers.

In regard to the production of colors it would be best to produce an alloy which is colored throughout. However, this is impossible at the present time as far as the author knows. The next best procedure would be to color the surface of the alloy. Some work has been done

NUMBER
FW
This equipment and/or parts thereof is covered by one or more of the following U. S. Letters Patent.
FOSTER WHEELER CORPORATION
NEW YORK N.Y. U.S.A.
THIS EQUIPMENT
IS THE PROPERTY OF THE
R-G MILK PRODUCTS, INC.
788 ST. ANN'S AVE.. MELROSE 5-3350
TO BE USED FOR R-G MILK PRODUCTS
AND
EBLING'S ICE CREAM ONLY

Name plates made from an aluminum base metal. After printing the letters on the plate, the plate is immersed in an etching solution. The plate is then removed and washed, and

in this field but nothing too exciting has been produced. A method has been developed which consists of immersing the alloy in a solution containing sulfuric and chromic acids. This forms a surface mordant which can then be dipped into a dye solution, thereby forming a colored lake. This is fully described in U. S. Patent 1,893,821, issued to Colin G. Fink.

Another interesting method which has been patented consists of depositing a layer of copper on the stainless steel and then heat-treating the copper coating. By this method beautiful colors can be obtained. The copper plated objects can then be plated with "Electrocolor" as described in the first part of this article. By this method it is possible to color stainless steel a variety of hues. Also the copper plate can be plated over with brass, bronze and other colored deposits and these can be treated as described in earlier articles of this series. However, these shades are undoubtedly the result of an oxide film which is not very corrosion resistant and must therefore be protected by a lacquer film. If this is true, it would be better to use a colored lacquer in the first place and omit the step of applying the copper plate.

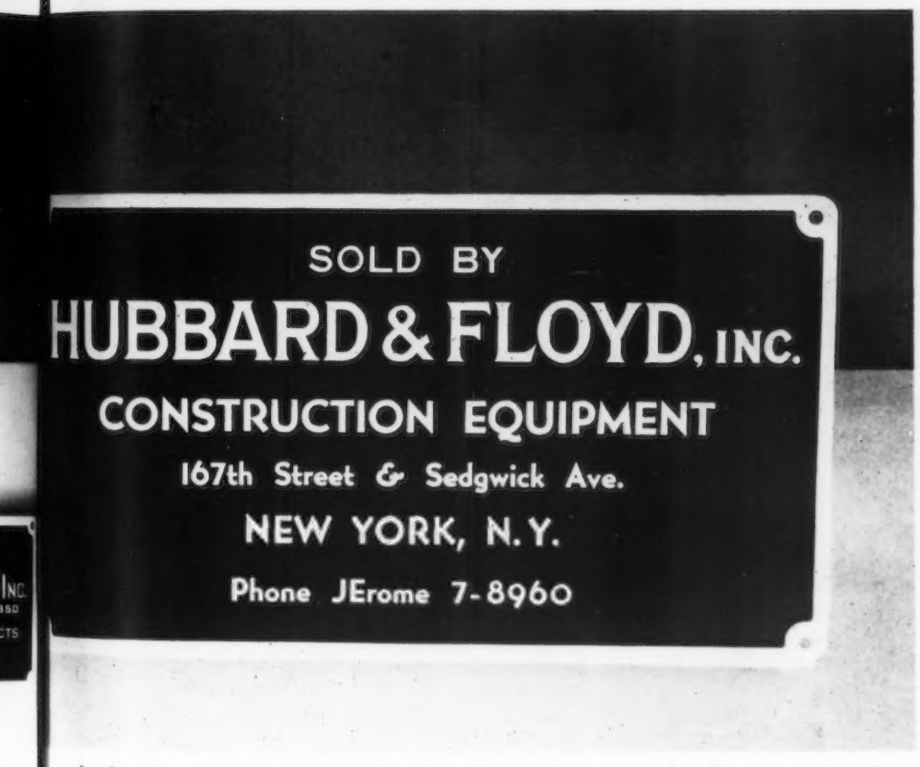
As would be expected colors can be obtained by heat treating stainless steel. A. L. Field has patented a method (U. S. Patent 1,977,270) of cleaning and coloring chromium steels and chromium nickel steels. After pickling the alloys are heated until the desired color is produced. The colors obtained progressively, it is claimed, are: light straw, dark straw, yellowish-brown, red-brown, deep purple, violet, blue and green. A temperature of 600 deg. F. produces an old gold color. However, the exact shade also depends upon other variables such as rate of heating and composition of the atmosphere surrounding the object. For example, it is known that if 18–8 alloys are heated to 1,560 deg. F. for various periods in a controlled reducing atmosphere of known humidity containing a small percentage of oxidizing gases, color films are produced on the alloy surfaces which range through the visible spectrum.

There are two methods which are being groomed for commercial release in the future. One is the Coloron process of the Allegheny-Ludlum Steel Corp. The author has no definite information of this process. However, Lippert (*Iron Age*, April 6, 1939, pp. 39–44) states that two basic colors are very attractive. These are a blue black and a gold bronze. These may be varied to produce other colors.

The coloring of stainless steel is commercially feasible and soon a method undoubtedly will be placed on the market for obtaining many hues. However, before this can be accomplished, research must show the way. It is a well known fact that some kind of film is formed on stainless alloys which gives the material resistance to corrosion. If this film be made thicker and then impregnated with a dye, any color of the rainbow can be obtained. Some work has been done in this field which does not promise success too soon in this particular research. The oil soluble dyes seem to offer more promise than the other types. This type of coloring material does not, however, give the live colors which are produced by the other kinds of dyes.

Concerning the heat treating and controlled atmosphere method, it should be possible to produce a variety of colors by the proper selection of conditions. It will be recalled that all the constituents of stainless steel, iron, nickel and chromium, produce colored salts. Iron gives a variety of colors which vary from orange and red to green and black. Nickel gives such colors as green, yellow, violet, red, and black. Chromium is just as varied with its colored compounds as red, green, blue, and black are quite easily produced.

When the metals mentioned are mixed it would be unsound to say that all of their color production properties are destroyed. True, many of the individual compounds cannot be obtained in the manner used heretofore because of the presence and therefore the interference of other metals and their compounds. However, by a well organized and directed research it should be quite possible to ferret out the correct procedures necessary to produce many interesting colored hues on stainless steel.



plated with new black nickel bath. After the relief is removed with an organic solvent a clear lacquer is applied with a spray gun

New Black Finish. At the recent meeting of the American Electroplating Society held in June, 1939, a new solution for producing an attractive black was revealed by the research department of E. I. du Pont. The bath contains the following compounds:

Nickel Sulphate, $NiSO_4 7H_2O$ *(3–4 oz. per gal.)*

Boric acid, H_3BO_3 *(2 oz. per gal.)*

Ammonium molybdate $(NH_4)_2\ MoO_4$ *(4–5 oz. per gal.)*

pH *(4.3–5)*

This bath should be used at 160–170 deg. F. with 2–5 amp. per sq. After cleaning, the objects which are to be colored black are made the cathode in the solution. The coating produced is deposited at a very fast rate at first but gradually slows down as the time increases. In 10 minutes 0.001 in. can be deposited at the current densities given. The coating takes well on either zinc or aluminum. Thus, for plating steel, or other metals, it is best to deposit a thin layer of zinc first and then follow with the black deposit. The deposit produced is a very attractive jet black which can be used for decorative work. Because of the speed at which the coating is obtained the deposit should find many interesting applications. It was noted by the author, however, that the coatings are more or less brittle and therefore will not stand very much bending. This will not affect the value of the deposit when it is placed on objects which are thick or which are able to resist bending of any kind.

Molding in rubber. Here are shown the two halves of the plaster supporting shell and the split rubber mold. The figure to the right was cast in the rubber mold

RUBBER MOLDS

For Casting of Metals and Plastics

GEORGE D. KRATZ
Vultex Chemical Company

MANUFACTURE of low-temperature molded parts has been, with few exceptions, along well standardized lines using recognized foundry or machine shop practices, and has followed substantially the same procedures for many years. The greater proportion of molds, made of steel or brass, were expensive, their cost increasing with the amount of engraving required. When fusible aluminum or lead molds came into use cost was somewhat reduced, but a master cast was necessary and the price of the master cast was often prohibitive for small lot production.

The best material for molds should be low in cost, readily handled and of such flexibility that parts designed with undercuts could be cast in the mold and the mold removed. Rubber molds made from prevulcanized latex solutions meet most of these requirements.

Where mixtures of the alum type are employed, the procedure is simple. The object to be duplicated, whether of bronze, marble, plaster, plastic, or other material, is simply sprayed with, or dipped successively into, the proper type of prevulcanized latex solution until the desired thickness of rubber is built up. It is thoroughly dried and then incased in a two-piece plaster shell which serves as a support for the rubber mold. When the plaster has set, the shell is opened, the rubber mold stripped from the model and the mold is replaced in the plaster shell. A pouring gate is put in the plaster shell and the mold is ready for use.

Usually the rigidity of the rubber mold itself is not sufficient to hold, without distortion, the material poured into it. Therefore, the shell of plaster or other material is put around it. Although the rubber can be built up to almost any desired thickness to prevent distortion when the cast is made, it is usually not practical to do so. One of the chief advantages in using rubber molds is that the mold can be stripped from the model and pieces molded even though portions may be greatly undercut. This operation becomes difficult if the wall of the rubber mold is too thick. A rubber thickness of $\frac{1}{8}$ in. or $\frac{3}{32}$ in. is about the limit.

By using rubber molds, expensive bronzes and other objects of art may be reproduced in plaster, alum mixtures

and a variety of other materials which when painted or gilded can be sold at a fraction of the cost of the original. With certain modifications, the same is true of phenolic and resinous plastics which can be cast and of certain metals and alloys.

None of the alum type mixtures have any pronounced chemical action on the rubber. Heat is not required and the molds can be used almost indefinitely. Mold life is usually dependent upon the handling care.

With plastics, however, there may be a two-way chemical reaction between the rubber and the plastic material. This may hasten the deterioration of the rubber mold and conversely, the rubber may discolor or otherwise affect the plastic. The latter, however, is not always serious as it is usually a surface effect which can be removed by buffing. What is far more important in so far as the life of the mold is concerned, is that most plastics, even where accelerators assist as catalysts, require a baking process of from a few hours to possibly several days. Unless the rubber employed is carefully compounded for this specific purpose, the life of the mold will be short and will vary inversely with the time and temperature required to cure the plastic.

Procedure With Plastics

The mold is made in the previously described manner. The plastic, usually of the phenol-formaldehyde type, is poured at a temperature of approximately 90 deg. C. and the whole placed in a curing oven at about the same temperature. The time of curing, ordinarily at least 24 hours up to three or four days is carried on over a range of decreasing temperatures until the condensation is complete. Sometimes the procedure is reversed, pour being made at room temperature and temperature gradually increased while the cure is being effected. It is then placed in the curing oven for a period of from 24 hours to five or six days, according to the type of resin. In either method, the rubber is in contact with the hot plastic for approximately the same length of time.

Many resins, after being poured will first liquify in the oven, then go through a gelatinous stage and finally harden. When the gelatinous stage is reached, it is sometimes possible to remove the cast from the rubber mold, although this is not advisable if the cast has undercuts or other features which tend to strain the relatively weak material. It is usually better to allow the condensation to be completed before attempting to remove the rubber mold.

The above procedure may be regarded as being in the experimental stage at present. There are, of course, many difficulties to be worked out, one of these being the proper compounding of rubber to increase the life of the mold. At present, four to five castings from the same mold are not unusual; much higher figures have been reported. As yet the casting of plastics in rubber molds needs a great deal of investigation to make the process comparable with the casting of the alum condensations, which are made without the use of heat. The possibility of the discoloring of the plastic by the rubber has already been mentioned. Sometimes there is a tendency for bubble formation at the wall of the mold. If caused by the rubber this can usually be overcome by proper compounding. The method is already practical in a small way and will find wider use in the near future. The Ralph Mancusco's nine-foot plastic statues in the Federal Building at the New York World's Fair were cast in rubber molds made from prevulcanized latex. The statues are exceptional not only in size but also in method of construction and simply serve as an example of this type of molding.

In another still newer field, low-melting metal allows are being cast in rubber molds. Under certain conditions, even lead itself with a melting point of 326 deg. C. can be cast readily without scorching the rubber mold or causing it to lose definition. The most-used metals for casting in rubber are the different alloys of bismuth, lead, tin, and cadmium sold under various trade names. They melt at 160 to 270 deg. F. Those alloys which can be liquified in hot water find particular favor. One of these has the desirable feature of expanding slightly on cooling, which tends to compensate for the normal contraction in the rubber mold. The shrinkage of rubber molds is usually small, possibly less than $\frac{1}{8}$ in. per ft., but it is still great enough to require compensation if precision parts are to be molded.

The method of making the mold and casting a low-melting alloy of the above type is similar to that previously described, with the exception that the process is much simpler than when using plastic compositions. The metal is melted in hot water and poured into the mold. Some water may be transferred at the same time. The presence of a small amount of water when making the pour is said to be desirable because it is believed to form a film around the cast and thereby increase mold life.

After the pour is made and has solidified, the rubber mold is removed from the plaster shell and plunged into cold water. This not only increases the life of the mold itself but also, tends to impart a fine-grained, ductile structure to the casts of alloys of the Woods-metal type. This method is recommended if the cast is to be enameled or otherwise surface-treated. With slower cooling, a coarser crystalline structure results and the cast may be brittle. Many of the small metal statuettes in the General Motors exhibit at the New York World's Fair were cast in this manner.

Where this process is used for the duplication of expensive pieces, most of which are thin, the production life of the mold is almost indefinite, thousands of casts being reported from a single indenture. In making small statuettes, 300 to 400 casts, cooled normally without immersion in cold water, are often obtained from a single vulcanized latex mold.

Making Metal Casts

As all rubber molds distort somewhat when not in use, it is advisable to leave the last cast in the mold when operations are discontinued. This applies to all methods described.

When casting novelty jewelry and ornaments, the principle of the operation is to work quickly and cool the metal rapidly so that the rubber will not be scorched nor the definition of the cavity impaired. To this end, a highly-compounded prevulcanized latex batter is prepared, containing the necessary vulcanizing ingredients and a minimum of water. The batch is then run through a mixing mill several times and sheeted into a slab of about $\frac{1}{2}$ in. thickness. During this operation, most of the water is eliminated. The rubber remains sufficiently pliable to take an impression of the object to be duplicated.

A two-piece mold is then prepared from the rubber slab, and the contacting surfaces treated to prevent adhesion during the vulcanization process. The ornament is then placed between the slabs and the whole vulcanized in a hydraulic press in the usual manner. Because an appreciable amount of water remains in the batch, the resulting mold may be somewhat porous, but experience has shown that the resulting impression is usually perfect. Milled rubber of the tread-stock type may also be used but longer life is claimed from rubber prepared from prevulcanized latex compositions. After vulcanizing, the mold is opened, the piece removed, the mold vented and the metal, usually lead, is poured in through a metal or earthenware funnel. The mold is clamped and whirled rapidly for 10 seconds. The whirling throws the metal against the walls of the cavity, covering a large area quickly. Thus the metal cools rapidly and does not have time to scorch the rubber mold.

The use of rubber molds in casting processes either for original objects or the duplication of standard pieces has attracted mostly the attention of small producers. The process requires little investment, the materials are readily obtainable, and the process does not require any particular skill.

SPOT-WELDED STRUCTURES-II

Designed for Stainless Steel

G. G. CUDHEA
Fleetwings, Inc.

IN THE DESIGN of any truss type structure the two primary considerations are the type of member to be used and the joints between these members. These two are so closely interrelated that they can best be shown by illustrating some typical structures.

The wide range of sections available is illustrated by Fig. 9 and Fig. 10. All of these sections are made on the draw bench or rolled. The closed sections are welded together in an automatic roll welder and can be stocked at a relatively low cost as compared with conventional sections. This wide range insures use of the proper section in any structure. Some of the basic considerations in the selection of each of these sections and the type of structure in which they are used are illustrated. Since one of the most common uses of the truss in aircraft is in the conventional wing and control rib, many of these examples are based on types of structure that have actually been built by Fleetwings, Inc.

Fabricated Rolled Tubes

The last rib truss design illustrates the fabricated tube, a section which has numerous adaptations in aircraft structures. It is available in a wide range of gages and diameters, since it can be

(Continued on page 392)

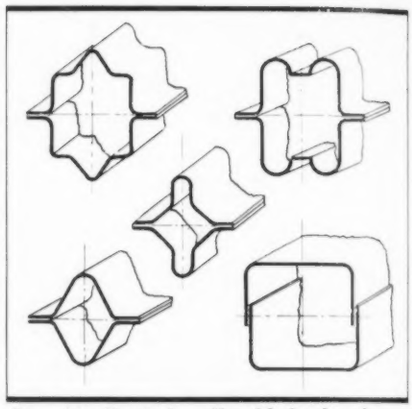
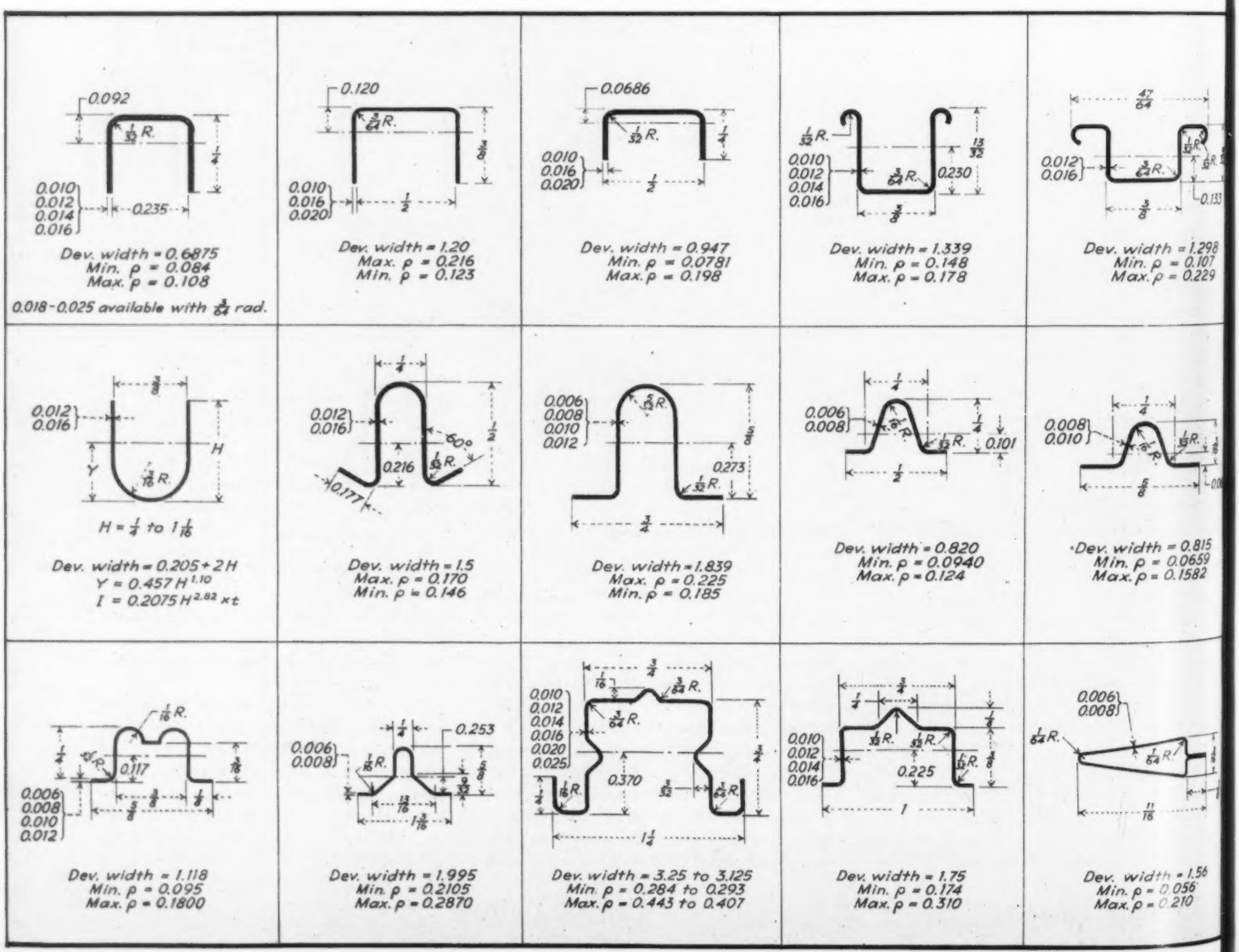
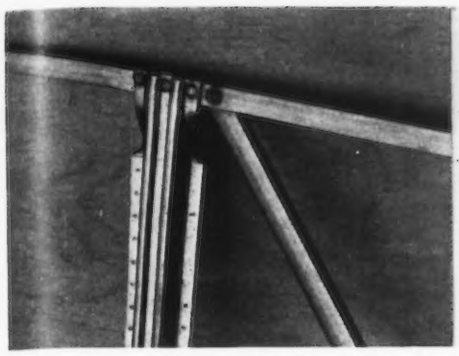
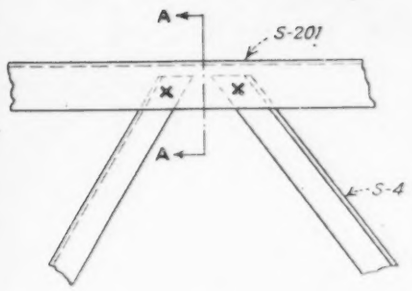


Fig. 10—Typical roll-welded closed sections available in stainless steel

Fig. 9—Typical draw-bench sections made of stainless steel sheets







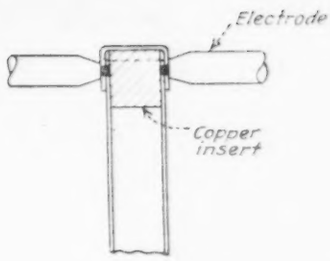


Fig. 11—Open channel sections, one of the commonest and cheapest types, used for relatively lightly loaded ribs as shown, and admirably suited to production fabrication. Outside dimension of the S4 section is the same as the inside dimension of the S201. Joints of this type can be assembled conveniently at a post welder, both legs of the web being welded to the cap in one operation by the use of a small copper insert. Since the stresses are low, no attempt is made to design the joints concentric. The distance required for convenient production welding governs the location of the web members. The angles between the web members are held constant if possible, so that the same insert can be used at all joints. A wide selection of channel sizes and gages is available since the rolls for this type of section are comparatively inexpensive

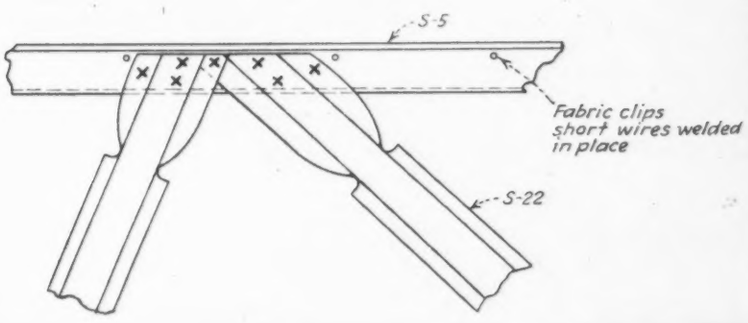
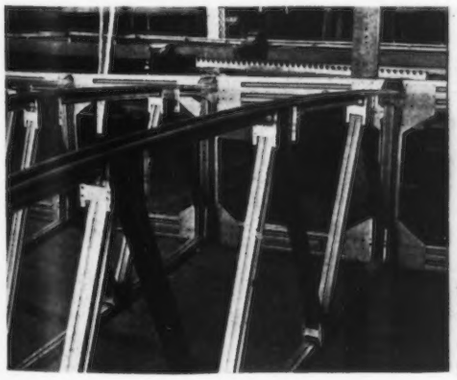


Fig. 12—Another type of rib commonly used. Here the cap is a modified channel section, S5, while the web is a closed section formed from two sections of the S22 type. The ends of the webs are formed by a stamping die. The rolled bead on the S5 channel increases its crippling stress. The center flat portion of the S22 section provides additional welds. This type of design is relatively efficient. However, if not carefully proportioned the web members are liable to fail at the ends



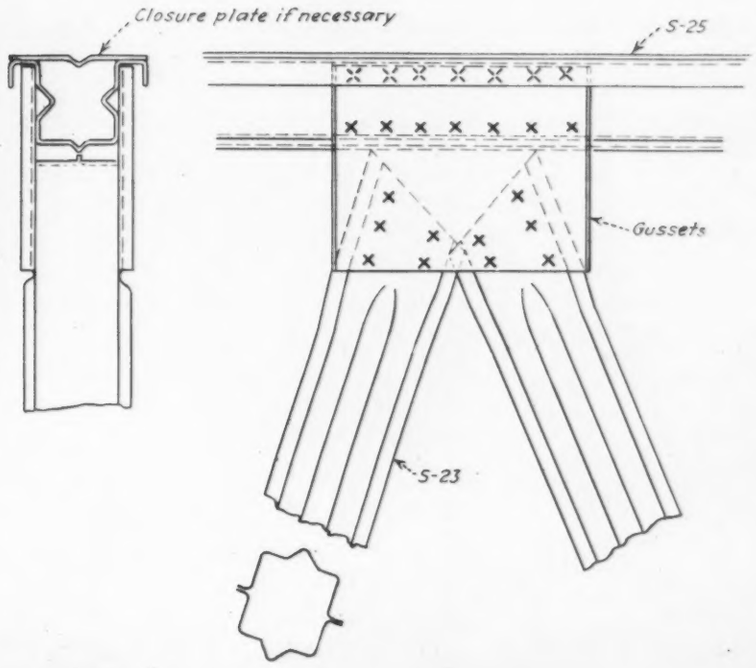


Fig. 13—A combination of highly efficient structural sections that lend themselves to low cost assembly. The rolled beads in both the S2 and S25 sections permit crippling stresses of 135,000 lb. to 140,000 lb. per sq.in. The free flanges of the S25 section provide a channel closure attachment. The closed S23 web sections can be taken from stock, cut to length, and the rolled bead flattened with a simple tool. The welding assembly procedure is as follows: (1) weld the gusset plate to the S23 rib sections; (2) assemble, join and weld the gussets to the S25 cap; (3) weld special closure strip, if strength requirements demand, to the flanges of the S25 sections

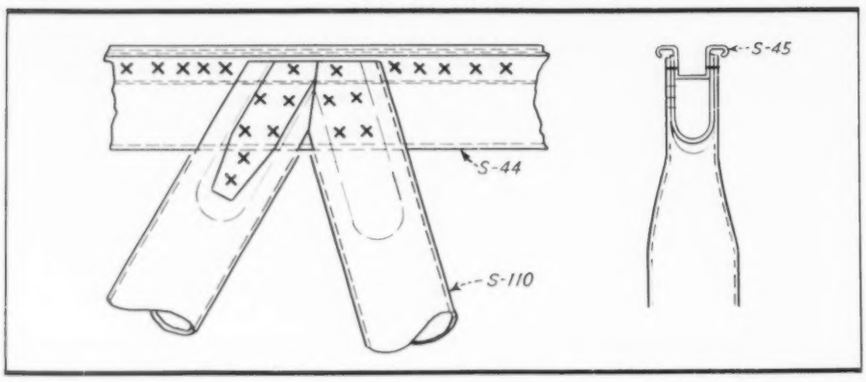


Fig. 14—Another type of highly loaded rib truss. The web members are manufactured from fabricated tubes. An S45 cap strip is used in combination with an S44 section, available with any length of free leg. The strength of the joint formed of two sheets of different thickness is increased by welding a plate outside the thinner of the two. Since the very efficient tubes required light gages, the attachments became critical. By the addition of the outside plate to the tube the joint becomes capable of developing the full strength of the web members. The assembly procedure is similar to that used in the preceding example. The tubes are drawn from stock, cut to length, and flattened slightly at the end in a special stamping die. The ends are slotted to fit over the U section. The special end plate is then welded on at the two lower welds only. Next, the tubes are welded to the U section. Finally, the S45 section closure is welded inside the U section. The figure shows one web member with the special end plate, and one without. These are illustrated in their order of cost

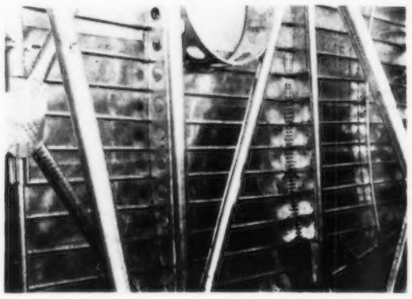


Fig. 15—Fabricated stainless steel constructions as used in an amphibian plane

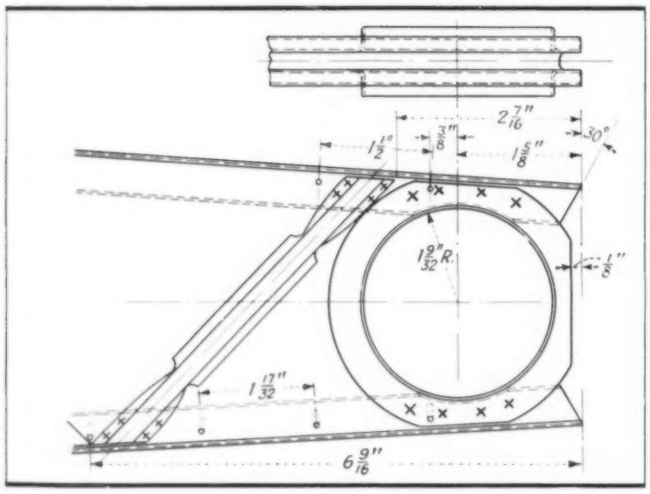


Fig. 16—Stabilizer joint, rib to spar, using a fabricated stainless steel type section as a beam

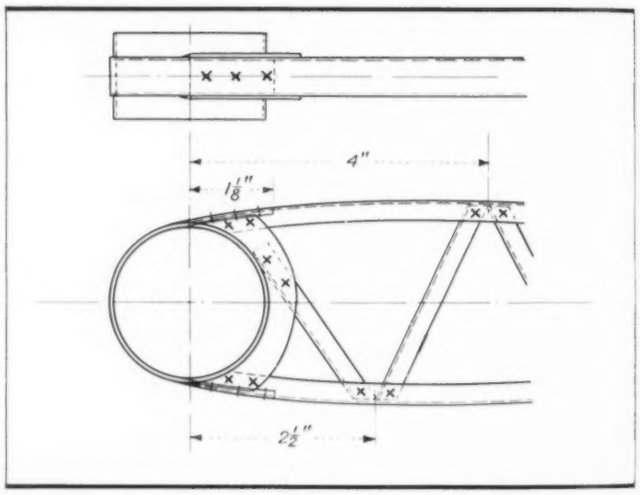


Fig. 17—Elevator joint, rib to torque tube, using a fabricated stainless steel section as a torque tube

formed either by rolling or on a brake. By virtue of the close weld spacing used in its fabrication it differs but little in strength and properties from conventional drawn steel tubes of the same tensile strength. A large number of tests of this type of section have been made by Fleetwings, Inc. The result of a typical pin-ended compression test is given to illustrate its relative efficiency. The details of the specimen are as follows:

Diameter .....2 in.
Thickness .....0.020 in.
Ultimate tensile strength
185,000 lb. per sq.in.
Length .....37.5 in.
0.35D .....0.70 in.
L/ρ 53.4
$A = 3.14 \times 0.020 \times 2$ ....0.1256 sq. in.
Load at failure.....10,500 lb.
Stress at failure 10,500/0.1356
83,000 lb. per sq.in.
D/t 100

No published values for chrome molybdenum tubes are available for comparison in this range of ultimate tensile strength. However, reference (a) gives the allowable stress in a 100,000 ultimate tensile strength S.A.E. 4130 steel tube for L/ρ 53.4 and D/t of 50 as 59,500 lb. per sq.in. No exact extrapolation of this value can be made. Inspection of the crushing stress curve for this type of tube, as given in Army-Navy Specifications ANC-5, "Strength of Aircraft Elements"; indicates that for a D/t of 100 the allowable crushing stress will be 62,000 lb. per sq.in., the ultimate will be 100,000 lb. per sq.in., approximately.

Torsion Tests

Torsion tests on the fabricated stainless steel type of section indicate that it follows with a fair degree of accuracy the generally accepted Donnell's theory, reference (b), for thin walled tubes in torsion. Fig. 15 illustrates the use of this section in a stainless steel amphibian which has been giving satisfactory service under severe conditions for the past three years. Figs. 16 and 17 show its use as a beam and torque tube respectively in control surfaces. These figures also illustrate the attachment of ribs to these members. The attachment flange shown in each case is a simple stamped section. In fabrication of a surface of this type the individual ribs are built as separate assemblies and welded to the flanges. After completion of all sub-assemblies the flanges are slid over the end of the tube in the proper order. An expanding copper mandrel is used as an insert to weld the flanges to the tube. As finally welded, the flanges provide stiffening diaphragms for the tube and tend to increase both its torsional and bending strength.

Question and Comment

Nomograph for Selection of Tap Drills

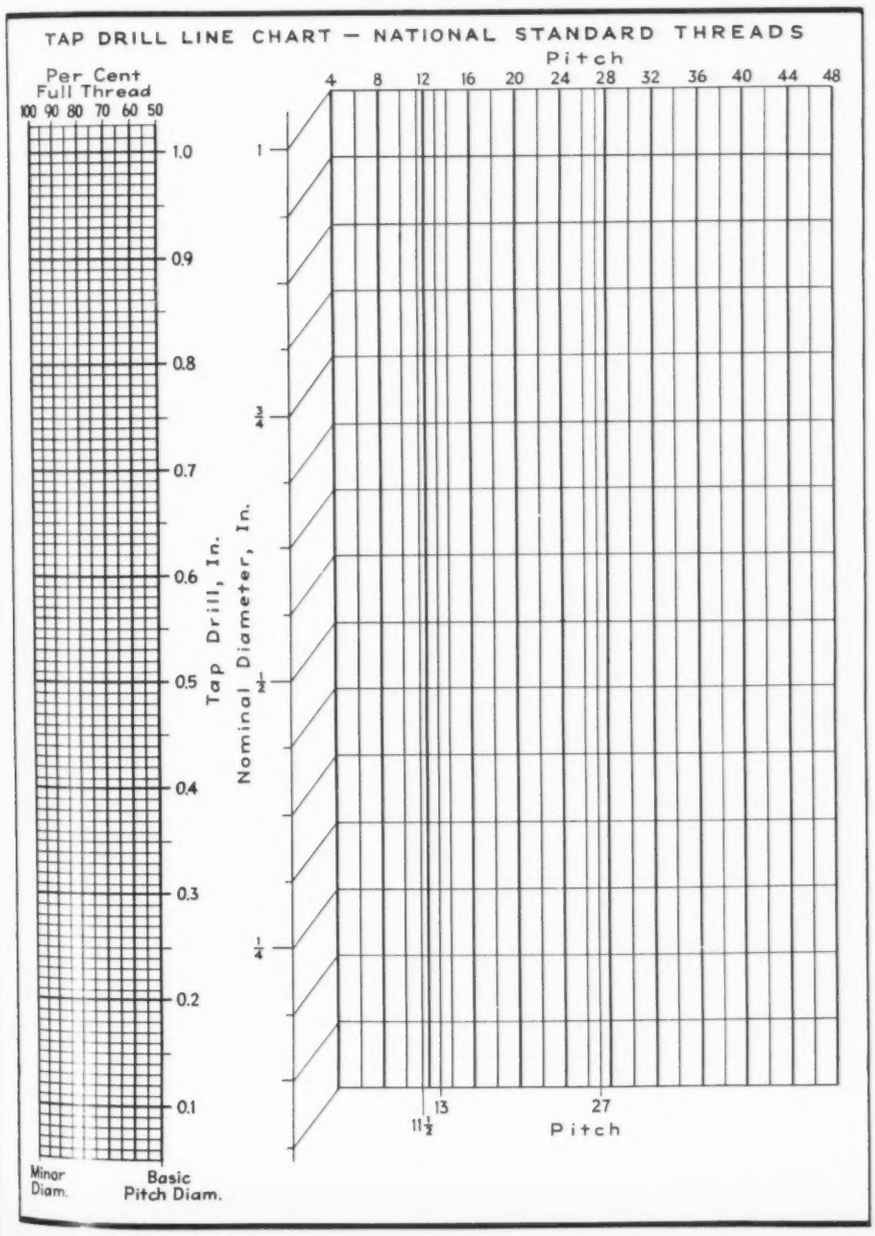
NORMAN W. TAYLOR

Having noted the attention you give to nomographs or so-called line charts and having found them to be real time savers I naturally have sought to apply the same principles to routine problems of my own.

My work in the screw machine products industry requires the checking of many odd-size screws and tap drills for the same. Seeking a quick, mistake-proof process, I developed this Drill Line Chart which I have found to be quite successful.

In using the chart, the customary celluloid rule with a hair-line on the under side is used. To determine the proper tap drill, connect the major diameter as indicated on the ordinate of nominal diameters with the intersection of the pitch ordinate and the major diameter abscissa. The continuation of the hair-line across the tap drill ordinates will indicate the proper drill according to the per cent of full thread desired.

By noting that the 100 per cent full thread ordinate is also the minor diameter ordinate and that the 50 per cent full thread ordinate is the basic pitch diameter ordinate, the chart becomes useful in selecting the proper thread where space is important. A good illustrative case is that of the selection of a thread for a sleeve and coupling. Also consider the choosing of a thread upset on a shaft.



Mixing Drinks Again

To the Editor:

The solution in *Product Engineering* for July, page 306, of Mr. H. E. Smith's wine dilution problem does not seem quite clear. Does he mean to evaluate the equation 129 times?

Here is a solution which I think is somewhat easier.

Starting with 100 per cent wine, the formula is

$$c = a\left(\frac{a-b}{a}\right)^n$$

In this equation c is the number of gal. wine left after n dippings of b gal. each, with equal replacements of water so as to keep the volume of mixture at a gal. In this problem $c = 0.15$, $a = 30$, $b = 1$. Substituting these values and solving by passing to logarithms, we find $n = 156.42$ dips required to reduce 100 per cent wine to one-half of one per cent wine content.

But the problem starts with 12 gal. wine in the mixture. Applying the same formula with $c = 12$, we find it required 27.05 dips to bring it from a 100 per cent wine content of 30 gal. down to 12 gal in the mixture. Therefore, the number of dips is $156.42 - 27.05 = 129.37$.

—CARL P. NACHOD
Nachod & U. S. Signal Co.

B.M.T. Subway Car

To the Editor:

As a reader of your magazine, I have always admired and held valuable much of the engineering data published therein. However, in the July number, page

280, you have an article on the new B.M.T. Subway car which calls for some corrections.

The buffing or impact resistance of the body walls is 200,000 lb., not 20,000 lb.

The traction motors, 8 in number, have a service rating of 55 hp. and a maximum rating of 70 hp. each instead of 720 hp. each.

—FRANK M. MILES
Brooklyn, N. Y.

Calculus?—No!

To the Editor:

The solution of the "Calculus" problem on page 306 of *Product Engineering* for July involves ordinary trigonometry.

This problem may be more easily visualized and its importance emphasized if we consider it as a Ferdinand problem wherein the bull with a ring in his nose is tethered to a post in the fence of a circular corral of unit radius by means of a rope of such length, r, that he can graze just one-half of the field. Although in the original problem, the desired value is called R_2, it will avoid confusion in this solution to drop the inferior number by calling it r.

Then, in the accompanying sketch, the area of one-half of the circle of unit radius equals the area of the sector EACB plus the areas of the two sectors OEDB minus the areas of the two triangles EOB. Stated algebraically with angles measured in radians,

$$\pi/2 = r^2\theta + 2(\pi/2 - \theta) - r\sin\theta$$

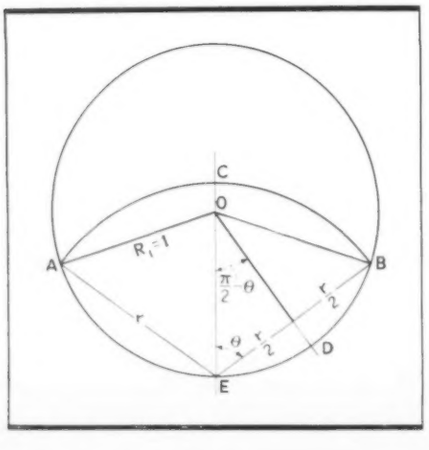
But from the sketch

$$\sin\theta = \sqrt{(1 - r^2/4)} \text{ and } \cos\theta = r/2$$

Changing from radians to degrees and substituting,

$$\cos\left[\frac{\pi/2 - r\sqrt{1 - r^2/4}}{2 - r^2}\right]\frac{360}{2\pi} - \frac{r}{2} = 0 = f(r)$$

The solution of this equation, which is expressed as a function of r, may be obtained to any desired precision by Newton's Method, but because the derivative is clumsy it is easier to get the slopes of the curve from increments. From a rough scale drawing get two fair guesses as to the value of r and substitute them successively in the expression.



The difference between the values of the function, thus obtained, divided by the difference between the two assumed values of the variable is the approximate value of the slope of the curve at those points. On dividing the value of the function by the value of the slope a minus correction to the variable is obtained. The process can be repeated until it gets beyond the capacity of available function tables and each step often adds several decimal places to the precision of the result.

We try $r_1 = 1.17$ and $r_2 = 1.18$ and obtain

$f(r_1) = -0.03247$ and $f(r_2) = 0.06433$

The slope then is

$$\frac{\Delta f(r)}{\Delta r} = \frac{(0.06433 - 0.03247)}{0.01} = 3.186$$

and the first correction $\frac{0.03247}{3.186} = 0.0102$

and the first corrected value of the function is $r_3 = 1.17 - 0.0102 = 1.1598$— and likewise the second correction gives $r_4 = 1.1589$—

Therefore, $R_2 = 1.1589R_1$ in the original problem.

—HARVEY S. PARDEE
Ravinia, Ill.

Is Industrial Design A Profession?

To the Editor:

I was much interested in Mr. Raymond Loewy's letter which appeared in *Product Engineering* for August, page 351.

The industrial designer I should classify as one with a professional calling. Assuredly he is consulted and employed for his ability to advise; certainly his is "an occupation that involves a liberal education and mental rather than manual labor" (though he may question the "manual labor"). And that, the dictionary tells us, is a profession or one of those things that go to qualify one as a professor.

If the designer is too professional in his manner, however, the hard-bitten industrialist thinks he's too arty and is apt to refer to him as a "sissy": if he isn't professional and fails to see the purple in a brown hillside the industrialist thinks he doesn't know his stuff. It must be tough to get a start, for, after all, it's his record of achievement that counts most.

There are some excellent designers who would go further if they weren't so arty—so different from those they are trying to serve. There are others who if they would put on a little "front" would go further. Those who seem to have gone the furthest have the ability, plus imagination, plus the human psychology and naturalness of being themselves. They are sufficiently practical that they have a business sense to support their artistic ability, and to those men seem to have gone the outstanding accomplishments and most of the business. In that small group Mr. Loewy should have no hesitancy in counting himself.

Well, I have done much more than answer the question. —H. S. SPENCER
General Plastics, Inc.

Simple Statement of Merit Better Than Comparison

To the Editor:

In the May number of *Product Engineering*, page 180, we find a very interesting article on "Engineering the New Rayon Machine" which has been brought to our attention by several people with regard to the invidious comparison between a cast iron design and a welded structure.

We cannot quite see the object of holding up a manifestly clumsy and ancient design of one material and comparing it with that developed by the American Bridge Company's engineer with the former as a target. Granted that the gray iron industry is still pretty much asleep in using the sales engineer and designer to push its wares, the foundry end of the business has improved by leaps and bounds and it must be admitted that the "comparative" school has been held down with considerable success in our advertising policies.

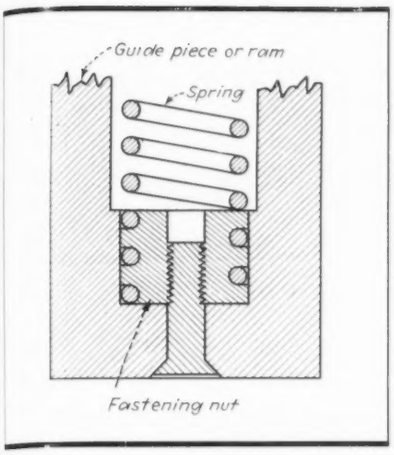
The Gray Iron Founders' Society recently employed the Battelle Memorial Institute to make a study of and condense into a report the modern literature on the engineering properties of gray iron. There are many metallurgists and engineers in the industry entirely competent to make such a study but we purposely chose an impartial research institute of high standing to do the work in order that the information obtained might be absolutely free from criticism of bias toward ingredients or process which so frequently is whispered when books, reports, etc., are published by those gaining their livelihood by the marketing of specific products advocated.

If a material or process has engineering merit it is sufficient so to state without comparison with other materials or processes. —W. W. ROSE
Gray Iron Founders Society

Spring Fastening Nut

To the Editor:

In presenting a problem encountered in the design of an air-operated work-holding ram (*Product Engineering* for



July, page 304), Mr. Paul E. Rudbeck stated that he is seeking useful ideas for holding the spring tight in the ram and guide pieces. Here is a suggestion in the form of a sketch.

As shown, it consists of a round nut, machined on the outside to accommodate the pitch and wire diameter of the spring. The internal thread serves to accommodate the hold-down bolt. Differentials in the pitch of the spring and the nut may be used to secure a tight fit between the two parts. This arrangement is equally effective for both tension and compression. —JACK SHAPIRO
New York, N. Y.

Shrinkage Stress Goblins

To the Editor:

In the May number of *Product Engineering*, page 203, is an article by H. V. Wenger, Jr., with reference to "Shrinkage Stresses in Arc Welded Structures." In reading through this article I find some excellent facts presented. However there are some items that I believe should be given further attention.

For example, Mr. Wenger states that arc welding is the casting of molten steel under rather unfavorable conditions. Following his idea throughout, if I were only casually acquainted with or interested in welding I think this statement would tend to drive me away from welding rather than toward it.

In the third column he says, "Distortion is probably a greater evil than residual stresses . . ." I am fully in accord with that. In other words, it is the external distortion rather than the internal locked up stresses which cause most of the headaches. However, he states, "Avoiding distortion is sure to increase the magnitude of the locked up stresses." While in some cases this may be true, on the other hand there is implied the idea that this may be rather serious.

In the last paragraph of page 203, the first sentence is excellent. However, at the top of page 204 where Mr. Wenger states, ". . . the resulting stresses may be dangerously high," conveys an idea which is neither borne out in practice nor by his preceding statement. For example, the usual rolled section. The standard I-section has considerable stresses in it at the time of purchase and to these are added the load stresses. Therefore, according to the statement, the beam should fail—but we know it doesn't. It is not at all out of reason to say that the usual 18,000 or 20,000 lb. per sq.in. of pulling stress is added to the locked up stress on the order of 30,000 lbs. Then what happens? The beam still works.

The reason I am bringing this matter to your attention is that there has been so much discussion about it. Because of the lack of knowledge in the average customer's or user's mind, shrinkage stresses are very mysterious to him and he becomes afraid of the results. Any article in an authoritative magazine which hints in the slightest that there may be no control over these unknown goblins of shrinkage stresses merely confirms the illogical ideas of the possible user. —E. W. P. SMITH
Lincoln Electric Company

To the Editor:

Mr. Smith is entirely correct concerning the advisability of avoiding any statements that will frighten prospective users of arc welding. I have read Mr. Smith's letter carefully and find only one criticism of any moment.

The paragraph at the top of page 204 is misleading as explained by Mr. Smith. The load imposed on a structure from an outside source seldom causes trouble. However a load of large magnitude may be imposed on the welded joint by the rigidity of the surrounding parts of the structure itself. The existence of these loads is verified by cracked welds in improperly welded structures.

An example from the author's experience was the fabrication of a large gear blank with four heavy spokes. The spokes were first welded to the hub and then three of the spokes were successfully welded to the heavy rim. The fourth spoke however refused to be welded without developing a crack in the weld on cooling, the reason being that the structure was too rigid to permit shrinking to take place without rupture. The trouble was overcome by welding the fourth spoke with a smaller electrode and lower welding heat.

Had the designer taken into account the locked up stresses and the resulting load imposed on the structure and specified the proper welding procedure the trouble would never have occurred. The article was written as a plea for designers for welding rather than to merely specify welding. —H. V. WENGER, JR.

Can You Work This One?

H. E. SMITH

Solution to August problem—

Keeping the Guards Away

In order to deliver one apple to the King, the servant picked 15 from the prize tree. Then, upon giving one-half of what he had plus one-half an apple, or 8 apples in all, to the first guard, he had 7 apples left. Following this same procedure, he next gave 4 to the second guard, leaving 3; and 2 to the third guard, leaving him with exactly 1 apple for the King. In those days, graft must have been a pretty serious problem!

This month's problem—

Five Smokers at Poker

Five men participating in an evening poker game were named Perkins, Reilly, Turner, Brown, and Jones. Each man was smoking a different brand of cigarettes, and Luckies, Camels, Chesterfields, Raleighs, and Old Golds were their brands, not necessarily respectively. At the beginning of the evening, they had 20, 15, 8, 6, and 3 cigarettes, but not necessarily respectively. At midnight,

1. Perkins draws three cards.
2. Reilly has smoked half of his cigarettes, or one less than Turner.
3. The man who smokes Chesterfields originally had as many more, plus one-half as many more, plus two and a half cigarettes more than he has now.
4. The man who draws to an inside straight inadvertently lights the tipped end of his fifth cigarette.
5. Brown draws as many aces as he had cigarettes.
6. The man who smokes Luckies has smoked two more cigarettes than anyone else, including Perkins.
7. No one has smoked all of his cigarettes.
8. The man who smokes Camels asks Jones to pass Brown's matches.

Determine from the above facts what brand each man smoked and how many cigarettes each had at the start of the game. This calls for simple mathematics, logic, and observation—but what engineering problem is not founded on these three things?

MOTOR DRIVES

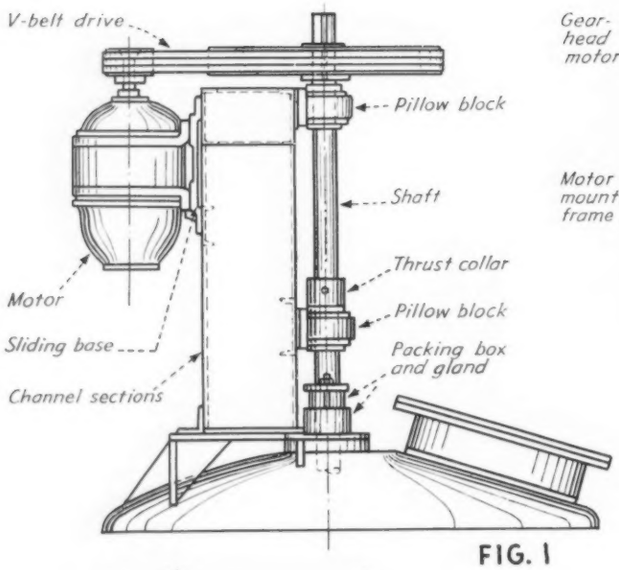


FIG. 1

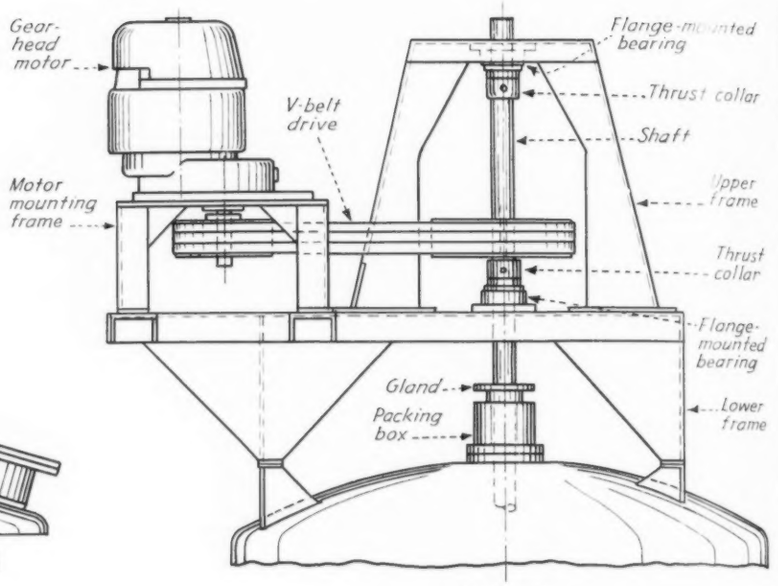


FIG. 4

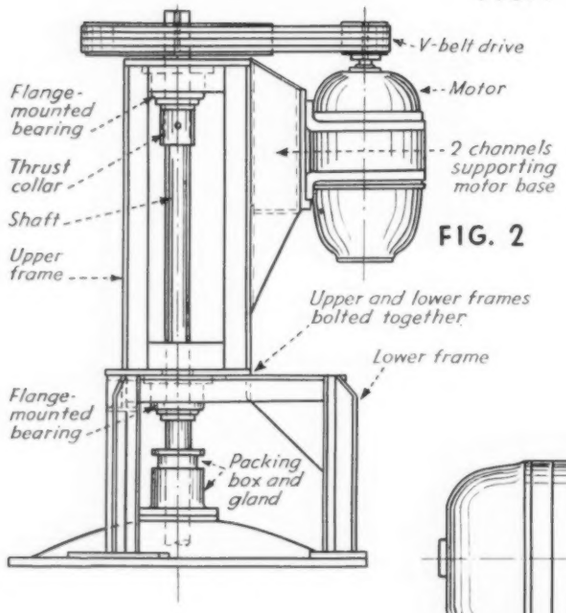


FIG. 2

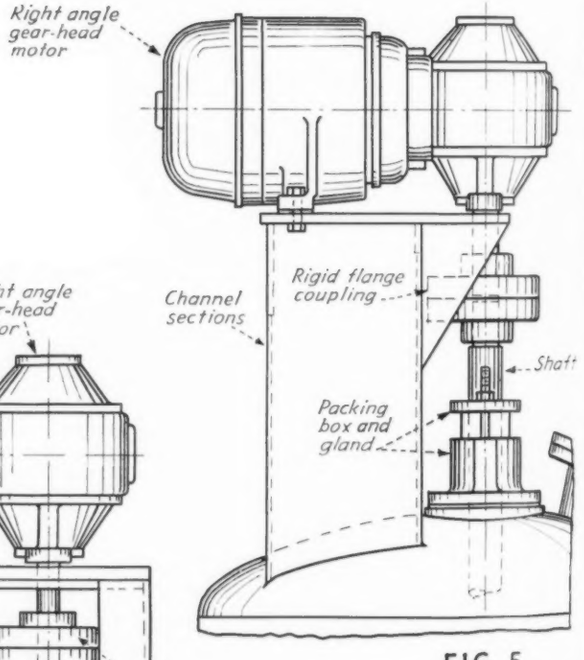


FIG. 5

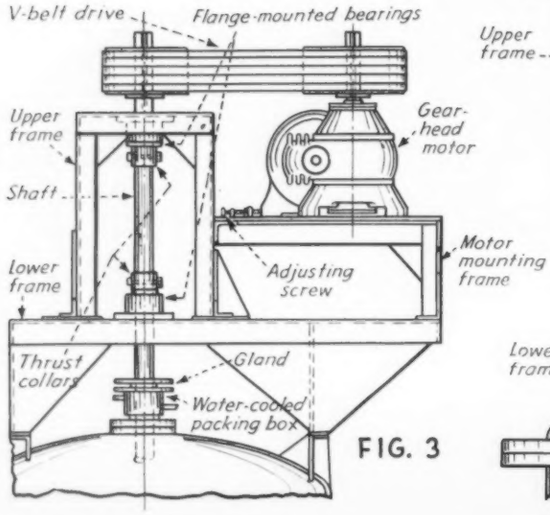


FIG. 3

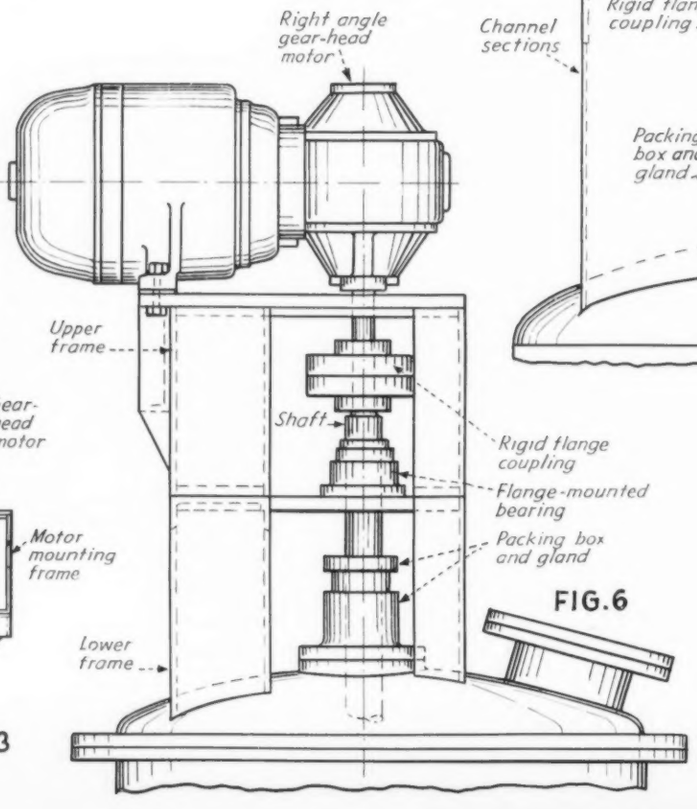


FIG.6

OR VERTICAL SHAFTS

H. D. SEYMOUR, *MONSANTO CHEMICAL COMPANY*

ALTHOUGH the vertical shaft drives shown on these pages are taken from agitating equipment, the methods for mounting the motor and shaft may be used in any similar applications. Choice of type of drive and construction of frame depends principally upon the following factors: torque requirements, available space, rigidity necessary, operating conditions and service requirements.

FIG. 1—For small load requirements, this mounting is rigid, takes up little space, and is readily accessible. Motor has sliding base to permit adjustment of V-belt drive. Frame is constructed of welded structural members.

FIG. 2—The frame of this small V-belt drive, suitable for light-duty applications, is fabricated of structural members, and is designed to provide easy access to the top of the agitator tank.

FIG. 3—For larger units, this drive uses a horizontally-mounted, gear-head motor and V-belt drive for compactness. Three demountable frame sections simplify construction.

FIG. 4—For large installations where head room is limited, this unit places the V-belt pulley between bearings to increase the distance center-to-center of the flange-mounted bearings. Heavy welded frame provides rigid support for the shaft. A compact gear-head motor was used to permit small pulley sizes.

FIG. 5—For light duty on short shafts which are not subjected to bending loads, this type of drive has simple construction. The entire bearing load is taken by the bearings in the right-angle, gear-head motor. Gear-head motor permits use of an output shaft larger than standard for increased rigidity.

FIG. 6—Differing from Fig. 5 in that it has an added flange-mounted bearing to increase shaft rigidity and to permit the use of a longer shaft, this unit also has one leg of the frame offset to increase the accessibility of the agitator tank top.

FIG. 7—This represents the simplest type of direct-connected vertical flange-mounted gear-head motor drive. Cylindrical support is rigid and easily constructed. This type of drive requires large head room.

FIG. 8—An adaptation of a parallel gear-head motor to a vertical drive, this unit uses a flange-mounted bearing to decrease the load on the motor bearings. Lower frame is fabricated with high rigidity for bolting to tank flange.

FIG. 9—Vertical flange-mounted, gear-head motor drive for large units where the duty is severe. An auxiliary bearing increases the rigidity of the shaft mountings and heavy I-beam sections form a strong welded frame. This type of mounting is for cases where headroom is not limited.

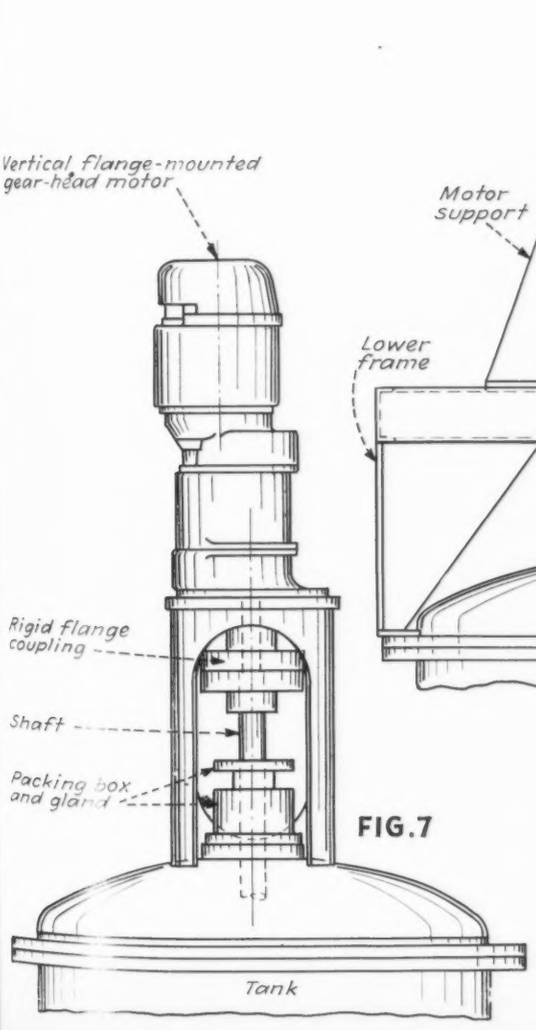


FIG. 7

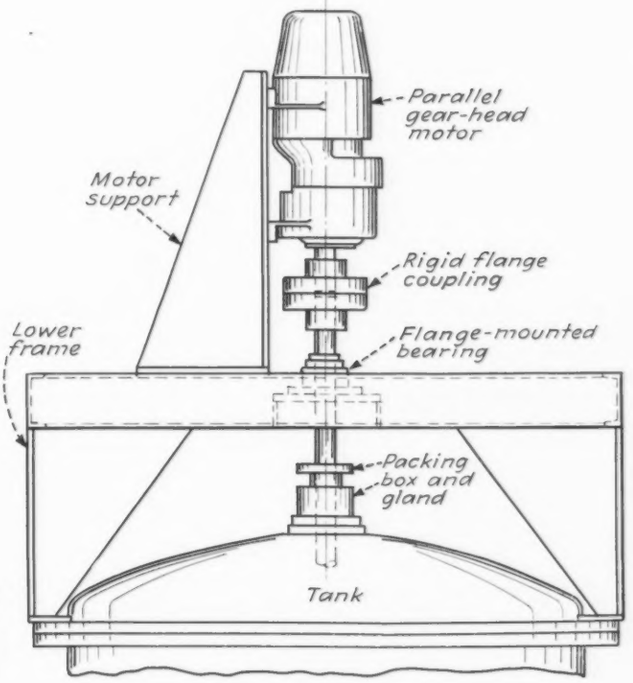


FIG. 8

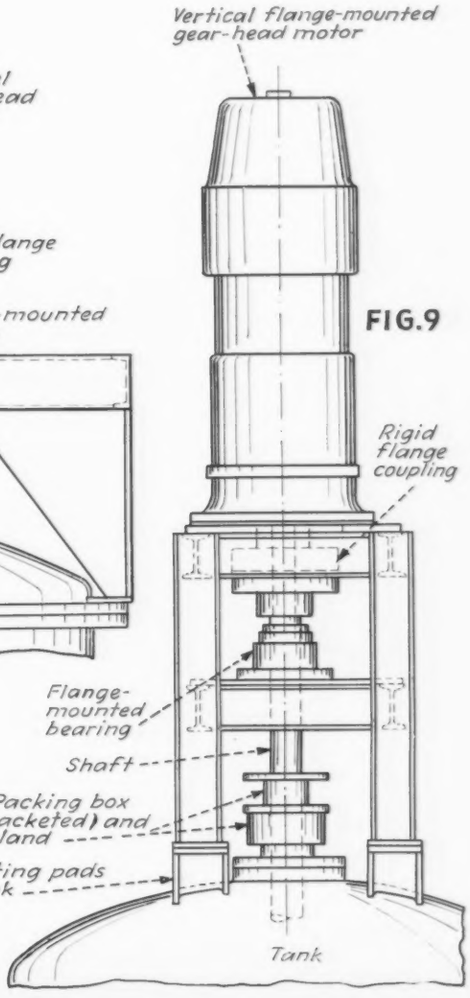


FIG. 9

News

Iron Molds Made by Electrodeposition Open New Reproduction Possibilities

New process, capable of reproducing intricate patterns, can be applied to molding of plastics, ceramics, glass, metal, rubber

DEVELOPMENT of a new process of electroforming iron molds which can be used to reproduce objects as delicate as phonograph records, was recently reported to the American Chemical Society by a group of chemists of the United States Rubber Company. Already being applied to a wide variety of industries such as rubber and plastic molding, ceramics, metal stampings, jewelry, silverware, and glass, the process can reproduce patterns which have 7,400 lines in an inch of surface.

The process consists of coating the object to be copied with a layer of electrically deposited iron, and then separating the metal from the object. The iron molds thus formed, which are usually 0.375 in. in thickness, are strengthened before using by mounting them on a suitable frame or backing. Mounting may be done in a number of ways, depending on the service requirements. If the object is circular it can usually be fitted into a frame of machined steel or cast iron. Irregular shapes can be backed with cast metal, such as aluminum or iron, or in some cases with sprayed metal. When the pressure requirements are low and heat conductivity is unimportant, plaster of paris can be used.

Where it is desired to make duplicates of an existing mold, a pattern, preferably of metal, is prepared from the mold and plated with iron. Some molds for rubber goods have undercuts, and in these cases it is necessary to make the patterns of rubber so that they can be removed from the mold without breakage. (The exact reverse of this process is covered in the article "Rubber Molds for Casting of Metal and Plastics," appearing on page 388 of this number.)

The thickness of the iron deposited by the new process depends upon the requirements for the individual mold and the method by which the deposited metal is to be backed by other materials. For most purposes a 0.375 in. layer of electrolytic iron is satisfactory. It is possible to deposit this thickness in about two weeks, which compares favorably with the time required for engraving a complicated design.

The iron solution which has been developed has unusually good throwing power, that is, the particles of metal in solution are capable of being "thrown" into the delicate and intricate crevices of the pattern being copied. However, deep recesses offer some difficulties and may require special treatment, such as the use of metal inserts.

The process offers quick and perfect reproduction of the most intricate details, usually with a saving in cost. By its use, designs available in one material, such as carved ivory, can be used to produce molds in which the original design may be duplicated in other materials, such as glass or plastics. It permits the reproduction of rare designs and old pieces where only a single sample may be available.

New "Trail Blazer" of Pennsylvania Railroad, designed to give maximum passenger comfort in 17-hour New York-Chicago service, features adjustable reclining seats with foamed-rubber cushions, dimmed lights at night, mechanical air-conditioning, and radio-equipped lounge-observation car. Coach interiors, decorated in tones of green and brown, have wooden window sills to eliminate "cold" feeling of metal, and metal parts of aluminum which does not stain luggage and clothing. Two-car dining unit, with air-controlled partition doors and polarized glass windows, is stainless steel equipped. Rubber-cushioned draft gear and tight-lock couplings with machined faces eliminate starting jolts.

Compact Turbine Unit Announced in England

TRIALS have recently been completed in England on a new and compact steam turbine system, known as the MacLeod geared turbine marine unit. The new unit, according to its designers, combines high efficiency, light weight, small dimensions, and ease and speed in maneuvering.

The unit tested develops 2,500 shaft hp. Complete with condenser, oil pump, thrust block, and reversing gear, the entire unit weighs only about 28 tons. It is 9 ft. high from the center of the propeller shaft and 14 ft. high overall from the bottom of the oil sump, and could be installed in an engine-room length of about 17½ ft.

By comparison, a reciprocating unit developing the same power would have a weight in the region of 153 tons and would stand 24 ft. high and take up over 31 ft. of engine-room length. It is claimed that the geared turbine unit would use about 30 per cent less fuel than the corresponding reciprocating systems.

New Industrial Uses Sought for Silver

SILVER RESEARCH, according to the Ninth Progress Report of the American Silver Producer's Project, now being financed for the third and final year, will be chiefly concerned with commercial applications of what is already known regarding silver. Among the many phases of silver now under study is its application to food containers. Several firms are working on the welding of fine silver sheet to a base metal backing. Silver-

clad base metals, made by rolling duplex ingots, are already in limited use. Excellent welds of silver-plated steel have recently been made at Rensselaer Polytechnic Institute.

In the field of electroplating, steady progress has been reported in the production of thin nonporous coatings by what may be called standard plating technique, but with special attention to cleanliness and the conditioning of the cathode surface.

Silver alloys have given the least return for the work undertaken of any of the fields thus far explored. No justification has yet been found for adding small amounts of silver to some largely used materials such as steel or brass. However, patents recently published reveal that the addition of several tenths of a per cent of silver to 18 and 8 stainless steel greatly reduces pitting and corrosion of this alloy in salt water.

Flame-descaling this 18,000-lb. steel hydraulic turbine casting with special Linde oxyacetylene equipment took one-fifth the time required for chipping. This relatively new process cracks scale from billets, blooms, slabs, forgings and steel castings as a result of differential expansion between the scale and base metal.

Generators of Future To Be Hydrogen-Cooled

PRACTICALLY all large turbine-generators of the future, by using hydrogen as a cooling agent, will be able to produce more kilowatt-hours of electric energy from each ton of coal, according to a recent statement by Mr. D. S. Snell, General Electric engineer.

The use of hydrogen in place of air as the cooling agent for turbine-generators results in a gain of nearly one per cent in full load efficiency and increases the output per pound of material about 20 per cent. This gain in efficiency results in fuel savings ranging from about $4,000 per year for a 31,250-kva., 3,600-r.p.m. machine to about $20,000 per year for a 200,000-kva., 1,800 r.p.m. unit. The increased output per pound of material obtained with hydrogen cooling allows the limit of output for generators of the 3,600 r.p.m. type to be increased from about 62,500 kva., the present limit with air cooling, to about 81,250 kva.

One important feature of the hydrogen-cooled generator is the arrangement for sealing the rotating shaft extensions against outward leakage of hydrogen. The arrangement employs a sealing ring, built integral with each generator bearing, to which vacuum-treated lubricating oil is supplied. This creates a film of oil between the sealing ring and the shaft which prevents the escape of hydrogen from the casing along the shaft.

Vacuum treatment of the oil supplied to the shaft seals, Mr. Snell explained, prevents contamination of the hydrogen with air that would otherwise be given up from the sealing oil, and also prevents the liberation of hydrogen from the oil into the bearing lubrication system.

Meetings

FOUNDRY EQUIPMENT MANUFACTURERS ASSOCIATION—*Annual meeting, Greenbrier Hotel, White Sulphur Springs, W. Va., Oct. 6-7. Arthur J. Tuscany, executive secretary, Penton Building, Cleveland, Ohio.*

PACKAGING INSTITUTE—*First annual meeting, Edgewater Beach Hotel, Chicago, October 12-13. H. L. Stratton, secretary, 342 Madison Ave., New York, N. Y.*

AMERICAN GEAR MANUFACTURERS ASSOCIATION—*Semi-annual meeting, Whitcomb Sulphur Springs, St Joseph, Mich., October 16-18. J. C. McQuiston, secretary, Shields Bldg., Wilkinsburg, Pa.*

AMERICAN SOCIETY FOR METALS—*1939 National Metals Congress and Exposition, Chicago, October 23-27. William H. Eisaman, secretary, 7016 Euclid Ave., Cleveland, Ohio.*

Large Interest Shown in Machine Tool Show

EXPECTED far to surpass in attendance and number of exhibitors the last machine tool show which was held in Cleveland in 1935, the 1939 Machine Tool Show of the National Machine Tool Builders Association will be held in Cleveland, October 4 to 13. "The purpose of the show is to place under one roof, for convenience, inspection and study, the finest and most modern machine tool equipment from every branch of the machine tool industry," stated President Wendell E. Whipp. "The last four years have shown substantial advances in the art of machine tool building—advances which mean reduced production costs, increased productivity per dollar invested, and greater potential profits."

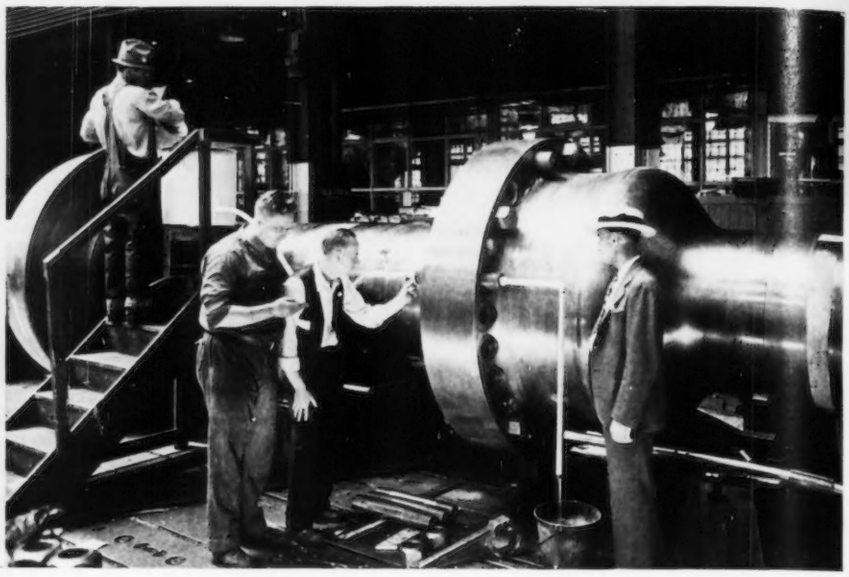
The show will be housed in Cleveland's $15,000,000 public auditorium, which contains over six acres of exhibition floors. The number of machines exhibited will run into the thousands. To provide the power required to operate the machines upon the exhibit floors, special power lines will be installed, carrying an 8,500 hp. connected load. Manufacturers from all over the United States and from many foreign countries are expected to visit the show.

Do You Know That—

TELEVISION will require 20,000,000 sq.ft. of plate glass, it is estimated, if it becomes as popular as radio. The glass is used for projection screens. (24)

FROM 20,000 ALUMINUM EXTRUDED SHAPES now available an engineer or architect can, almost without exception, select a cross-section which exactly meets his requirements. (25)

STANDARDS—the basis for today's mass production—existed as early as 1215 A.D. in this clause from the Magna Carta: "There shall be one measure of ale throughout our whole Kingdom and one measure of corn and one breadth of cloth, that is to say, two ells within the selveges; and it be of weights as measures." (26)



Assembling the three 30,000-kva, 13,800-volt Allis-Chalmers generators for TVA's Chickamauga Dam requires liberal use of dry ice in making shrink fits. At the left, the 93-in. diameter thrust collar is being lowered into place on the 34-in. generator shaft. The shaft was previously cooled to an outside temperature of 23 deg. F. by packing its hollow bore with dry ice. Felt wrapping prevented excessive moisture condensation. At the right, tight-fitting hollow 4-in. bolts for the coupling between the water wheel and generator shaft are assembled after shrinking by packing in dry ice. Bolts are shrunk for easy removal by piping alcohol cooled to minus 40 deg. F. through their hollow bore as shown.

Case Histories In Patent Law

H. A. TOULMIN, JR.

(EDITOR'S NOTE: *We wish to emphasize that in consenting to furnish this column wherein general explanations of the law in specific patent cases are set forth, Col. H. A. Toulmin, Jr. wants it clearly understood "that each actual case should be submitted to your own patent attorney who is the only one familiar enough to advise you accurately." The purpose of these explanations is to give a better general understanding of questions of patent law.*)

No. 13

QUESTION: To what degree of perfection is it necessary to bring an invention in order for it to be patentable?

ANSWER: Neither a general idea or conception, nor a device which will not work successfully is patentable. Since the patent law contemplates protecting only such inventions as promote the general welfare, the invention must *work*, or at least be so far advanced that it can be made to work by applying to it the ordinary skill of the art.

Most original patents are upon quite crude inventions. Some of the greatest have been of that sort, as for example, the incandescent lamp, the telephone and the airplane. Crudeness is no drawback. It is sufficient if the germ of the idea be fully and definitely disclosed and at least one way of using it be described. It is the task of the inventor, in short, to disclose the idea in so concrete a form that it can be developed by scientists, manufacturers and engineers. Such a case is that of the airbrake. When first invented it worked satisfactorily enough, but the original one would have been of practically no value on modern heavy, high-speed trains. It took a great deal of improvement to make the modern air-brake.

The invention must be far enough advanced so that the inventor can demonstrate with certainty the practical efficiency and utility of the invention. He must tell enough so that others skilled in the art can understand its workings and use and enjoy the invention. The disclosure must be in the form of drawings and descriptions, or in the device itself, or both.

To prevent the presentation to the patent office of half-baked, unfinished, unworkable ideas in nebulous form, the law encourages the inventor to delay making his disclosure until he is certain that the invention will work.

Here are some court decisions on this subject:

"The law requires not conjecture, but certainty. If the question relate to a machine, the conception must have been clothed in substantial forms which demonstrate at once its practical efficacy and utility."

Another: "A conception of the mind is not an invention until represented in some physical form, and unsuccessful experiments or projects, abandoned by the inventor, are equally destitute of that character."

Again: ". . . it is well settled that until the invention is so perfected and adapted to use it is not patentable . . ."

In the so-called Telephone Cases the Court said: "The law does not require that a discoverer or inventor, in order to get a patent for a process, must have succeeded in bringing his art to the highest degree of perfection. It is enough if he describes his method with sufficient clearness and precision to enable those skilled in the matter to understand what the process is, and if he points out some practical way of putting it into operation."

The invention may not even be in the commercial stage, as pointed out by the Supreme Court of the United States in the following decision: "It is not necessary, in order to sustain a generic patent, to show that the device is a commercial success. The machine patented may be imperfect in its operation; but if it embodies the generic principle, and works, that is if it actually and mechanically performs, though only in a crude way, the important function by which it makes the substantial change claimed for it in the art, it is enough."

New Materials and Parts

Thermostatic Starters

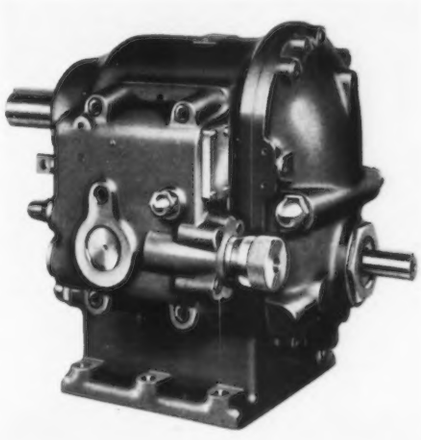
A new design of auxiliary breakers provides control and overload protection for a.c. or d.c. motors of 1 hp. or less, through thermostatic action. After overload, the handle automatically returns to the "off" position. When thermostat has cooled the mechanism relatches and is ready for starting by throwing the handle to the "on" position. Starter will stand a heavy starting load or an overload for a brief period of time without tripping, but will trip before the overload has continued sufficiently long to cause damage. Movable silver roll contact recedes into a recess in the base, effectively snuffing the arc. Manufactured in both single and double pole, and provides a quick make and quick break of its contacts which are silvered to insure long life. Trumbull Electric Mfg. Co., Plainville, Conn.

Felt Seal Bearing

By using a new and simple principle, these double felt sealed bearings have standard single row S.A.E. dimensions of bore, and inner and outer race widths. The seal prevents the entrance of dirt by contact of the felt fiber on the polished surfaces of the inner race, and by the utilization of the natural tendency of deflected felt to resume its original flat shape. Extensive tests have proved that the new seal retains the bearing lubricant and excludes any dust or dirt entry into the bearing itself. Friction drag is slight. Suitable over a large range of speeds, the new Red Seal bearing is available for shafts up to 1 in. in diameter. SKF Industries, Inc., Philadelphia, Pa.

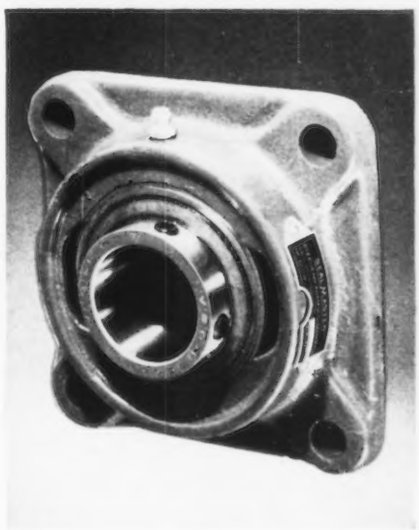
Hydraulic Transmission

Providing a speed range steplessly variable from 10 to 3,000 r.p.m., this new 2 hp. oil power variable speed transmission is especially designed for machine tool applications. Placing the oil power fluid motor directly over the multiple piston pump requires less space than putting the motor and pump in line, and results in a smaller and more compact unit. Controls are simple and extremely flexible. The machine has a high overall efficiency with high starting torque. There is no power loss in accelerating from standstill to maximum speed or in starting and stopping. No valves are used in reversing, and there are no rotary valves. Sundstrand Machine Tool Co., Rockford, Ill.



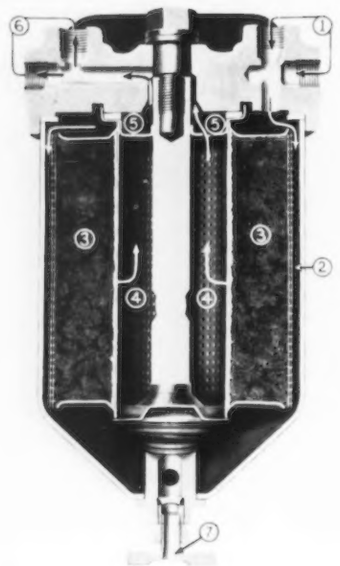
Bearing Units

Constituting an addition to the line, Sealmaster ball bearing units are now available in self contained flange and take-up units. Of the self-aligning type, these bearings feature a seal built in as an integral part of the bearing proper, effectively sealing the bearing against all foreign materials, and retaining the lubricant. Misalignment of the shaft cannot interfere with the effectiveness of the seal, for even though the bearing be removed from the housing, dirt cannot enter. Flange and take-up units are available with the same specifications as the standard duty cartridges used in the pillow blocks of the Sealmaster line. Stephens-Adamson Mfg. Co., Aurora, Ill.



Oil Filter

For the protection of bearings used on grinders, automatic screw machines, and other machine tools, this new oil filter is easily installed and removes all solid impurities such as fine metal chips. Its main parts and operation are as follows: 1. Unfiltered oil enters through optional



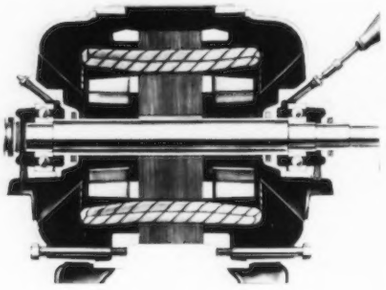
inlet; 2. Oil flows into drawn steel case; 3. Oil is forced through Igneonite filtering element; 4. Brass collector tube into which filtered oil enters after passing through filter element; 5. Clean oil passes through annular passage; 6. Clean oil discharged through optional outlet; 7. Drain cock for draining accumulated dirt and water from sump. A. C. Sparkplug Div. of General Motors Corp., Flint, Mich.

Brinell Machine

Designed specially for Brinell testing large and awkward parts such as castings and forgings, this new machine facilitates positioning of the part by having a large stationary table and a ram sufficiently long to cover the range of the machine. Operation is controlled by a lever on the side of the machine and the ram can be stopped in any position, permitting rapid testing of large production lots. Operation is hydraulic throughout, and a fractional-horsepower ball bearing motor drives the pump, the shaft of which is also ball bearing mounted. All working parts are bathed in oil, insuring long wear and minimum of maintenance costs. Two standard sizes are available: No. 1 has a throat depth of 6 in., maximum height of 12 in., table size of 12 x 20 in. No. 2 has throat depth of 9 in., maximum height of 18 in., table size of 17 x 24 in. Special machines to any dimensions can be built. Detroit Testing Machine Co., 5137 Trumbull Ave., Detroit, Mich.

Motor Lubrication

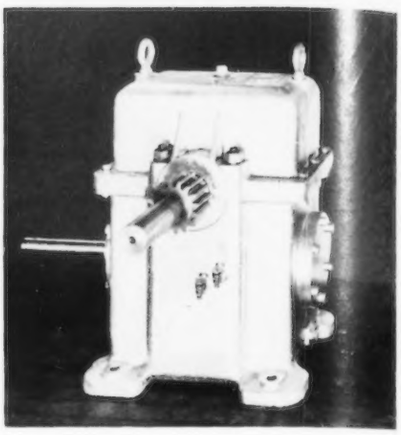
New method of bearing lubrication, known as Lubriflush, provides a means of ejecting the old devitalized grease from motor bearings so that the bearing



is replenished with clean lubricant throughout its retaining chamber. Through a duct leading from the outside of the motor, a new lubricant is injected to the inner side of the bearing with a pressure gun. A drain is placed on the opposite side underneath the bearing. Grease fitting and drain plug are readily accessible. This method, which prevents the retention of sludgy substances and residue, is now being applied to all U. S. motors. U. S. Electrical Motors, Inc., 200 E. Slauson Ave., Los Angeles, Calif.

Cone-Drive Reducers

A standard line of heavy-duty speed reducers incorporating the cone area-contact type of worm gearing are, capacity for capacity, roughly two-thirds the size of standard worm gear reducers, with a proportionate saving also in weight. The savings are due to the fact that the larger area per tooth and greater number of teeth in contact with the cone worm gearing permits a material reduction in center distances for the



same load capacity. High efficiencies, long life and quiet operation are claimed for the unit. The new standard line of cone drive speed reducers are of the vertical type with the worm on the bottom. They are designed for heavy duty service throughout. Anti-friction bearings are used throughout except for the sleeve bearings on the gear shaft in the largest units. Roller bearings are used in the gear shafts in the smaller and intermediate sizes. In the larger speed reducers, worm shafts are carried in ball thrust and roller radial bearings. Available in models ranging from 3 in. to 15½ in. center distance, with wide selection of standard ratios for each size. Michigan Tool Co., E. McNichols Rd., Detroit, Mich.

Coolant Pump

Model 11023-E Gusher coolant pump confines all unsightly piping and delivery passages to the inside of the machine housing, presenting a good appearance.

Installation of the pump, which is arranged for flange mounting against a pad on the side of the machine coolant reservoir, requires only 4 cap screws. The 3x5½-in. pump inlet opens directly into the reservoir, providing unrestricted gravity flow. Twin suction intakes which enter independently into the upper and lower "eyes" of the impeller give good efficiency and maintain an hydrostatically balanced thrust to counteract the weight of the vertical shaft. Pump has no packing glands, foot, relief or by-pass valves. There are no metal-to-metal contacts within the pump, enabling it to handle non-lubricating and abrasive-carrying liquids. Equipped with a ½-hp. built-in motor, this pump can supply soluble coolant in quantities up to 65 gal. per min.: 85 gal. per min. with a ¾ hp. motor. Ruthman Machinery Co., Front and Pike Sts., Cincinnati, Ohio.

Adjustable Transformer

More than doubling the amount of power controllable by a single unit, two new types of Variac transformers for voltage control are now available. Be-

cause of their high power-handling capacity, the Type 50 Variacs are especially suitable for applications where failure would be serious and where they are subjected to considerable abuse. The independent carbon brushes are mounted on a cast aluminum radiator, so shaped as to conduct heat rapidly from the region of the brushes. Type 50-A is for 115 volt service, and will handle 5 kva. Type 50-B, operating at 230 volts, will handle 7 kva. Suitable for either table or panel mounting. General Radio Co., 30 State St., Cambridge, Mass.

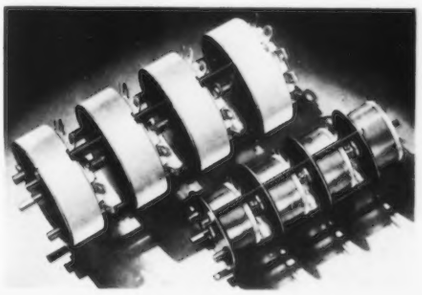
Cylinder Gage

For checking inside diameter, out-of-roundness and trueness of bore, for parts such as automobile cylinders and cylindrical work requiring great accuracy, this new gage features three adjustable locating contacts which permit quick and

positive location. The three locating contacts locate the two measuring points diametrically and perpendicularly with the cylinder. Centralization is assured for any diameter throughout the range of the gage. Locating contacts are set directly in relation to the nominal diameter of the cylinder. The motion of the sensitive contact is transmitted to the indicator directly through a rod which is suspended by a flat spring and a bellows spring. The Model 1200 cylinder gage is available in two ranges, 2⅞ to 5 in. diameter, and 5 to 10 in. diameter. Federal Products Corp., 1144 Eddy St., Providence, R. I.

Tap Switches

Tandem assemblies of 2, 3, 4 or more of the new Ohmite power tap switches, coupled together by special extended shafts and compactly assembled by through-bolts and insulated spacers, are



now available. They are easily mounted on panel by 3 screws. These tandem assemblies are used to switch both sides of a single-phase line or to switch all phases of a three-phase line; to provide simultaneous control of separate circuits; or for other applications. The shafts are completely insulated by strong steatite hubs. Four sizes of Ohmite power tap switches are available for single or tandem mountings. Details of the tap switch are given in *Product Engineering* for June, page 265. Ohmite Mfg. Co., Flournoy St., Chicago, Ill.

Precision Standards

A new set of precision measuring standards, under the tradename of Ultra-Chex, consists of nine standards accurate to 8 millionths in. and will make 71 combinations in steps of ⅛ in. up to 4⅞ in., and 41 combinations in steps of 0.1 in. up to 4.1 in. The set, available for less

than $20, places high precision accuracy within the reach of the small shop. Also available with the set is the Scherr Optical Parallel, accurate in planeness within 4 millionths in. George Scherr Co., Inc., 128 Lafayette St., New York, N. Y.

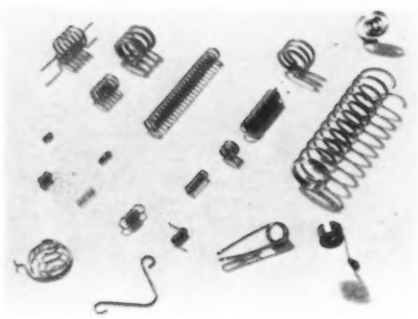
Protective Coatings For Magnesium Alloys

New protective and decorative coatings for magnesium alloys, known as Treatment No. 7 and Treatment No. 8 surpass other known treatments in protecting magnesium alloys against salt water, and upon general atmospheric exposure result in satisfactory adhesion surfaces for subsequent paint systems. They introduce no dimensional change, and may be used on parts machined to close tolerances. Treatment No. 7 is usually applied to parts after they have been machined, and gave a dark brown to black finish on most alloys, except Dowmetal M. Treatment No. 8 may be used on all forms and alloys including Dowmetal M. This treatment does not affect machined surfaces and leaves them with their original luster. Complete treatment is obtained on all surfaces, including the

bottom of the deep holes. Another protective coating, known as Dow. No. 6, in reality a dye coating produced in water solutions at high temperatures and pressures, can be furnished in colors ranging from yellow, red, blue, and green to metallic lusters such as bronze and brass. Dow Chemical Co., Midland, Mich.

Beryllium Copper Springs Made to Close Tolerances

Through new production and heat-treating methods developed by laboratory research, beryllium copper coil springs can now be supplied in production quantities at reasonable cost to close tolerances in length, diameter and deflection rate. Special production testing equipment employing the Electronic Micrometer method of "pressureless" gaging has been developed for inspection to these closer tolerances. Greater endurance strength, higher electrical



conductivity and reduced set or drift are obtained by using specially processed beryllium copper wire, with the coiling and heat-treating operations for each production lot predetermined by laboratory tests. Present facilities are designed to produce springs coiled from wire up to $\frac{1}{8}$ in. diameter, with a maximum coil diameter of 2 in., and in lengths up to 10 in. A complete stock of tested beryllium copper wire in all B&S gage sizes from 0.009 to 0.1285 in. is maintained for prompt shipment of trial or production orders. Instrument Specialties Co., Inc., Little Falls, N. J.

Heater Motors

Designed for use where rugged, quiet, efficient, constant duty motors are needed, such as in automobile heaters, these motors are wound for either 6 or 12 volts d.c., and have efficiencies ranging from 35 to 47 per cent, depending on the size. To prevent loss of lubricant and to eliminate the oil problem, sealed bearing retainers and efficient oil slingers are employed. Field coils are heavily taped and all live parts have ample clearance from metal parts to successfully guard

against grounding. Quietness is achieved through the use of ten flat commutators and inherently balanced armature windings. Commutators are diamond turned. Available in a variety of sizes ranging from 1/100 to 1/20 hp. Delco Appliance Div., 391 Lyell Ave., Rochester, N. Y.

Finish for Wood

Reducing the time required for ordinary wood finishing from 20 hr. to 5 hr. or less, a new finish, known as H.T.A. Zaponite, replaces three coats with one. The new process offers a method of applying, in one coat, half as much solids as formerly were used in the three-coat finish, yet obtains the body and fullness of the three-coat finish. The finish is applied by special apparatus that maintains a temperature just under 200 deg. F. at the spray gun nozzle. The work is then air-dried at room temperature for $\frac{1}{2}$ hr. to an hour; it is next force-dried two to three hours at 120 deg. F. to 140 deg. F. No sealer is required before application. Zapon Div., Atlas Powder Co., Stamford, Conn.

Wrinkle Finishes For Flexible Materials

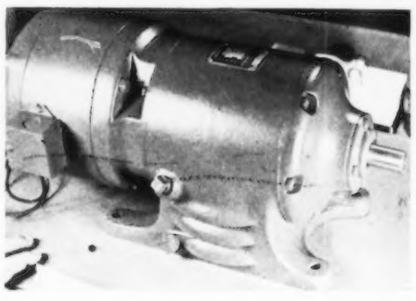
For coating flexible materials such as fabrics, paper, and leather, this new wrinkle finish is attractive and practical. Finish is applied by spraying, knifing, or is rolled on. The character of the finish causes it to dry into a wrinkle pattern of uniform texture. The texture may be varied from small to coarse, depending upon the requirements of the manufacturer. It will not chip or peel. New Wrinkle, Inc., Dayton, Ohio.

Vinyl Resin Sheets

Sheets of synthetic vinyl resins have the outstanding property of permanence of size and shape. Composed of a thermoplastic resin of copolymerized vinyl acetate and vinyl chloride, and known as "Vinylite" series 5 resins, the sheets are available in any color, transparent, translucent, or opaque. Three choices of finish are offered, calender, matte, or high gloss. No aging is required once they are manufactured, and they do not warp. They are completely non-flammable, and have low moisture absorption. Produced in the standard size of 20 x 50 in., and in standard thickness from 0.01 in. to 0.03 in. Also available in continuous rolls 22 in. wide. Sheets weigh approximately 84 lb. per cu. ft., and have a tensile strength of 8,000 to 10,000 lb. per sq. in. Carbide and Carbon Chemicals Corp., 205 E. 42nd St., New York, N. Y.

Speed Reducer

This new motorized reduction unit, constituting an addition to the Type SME straight-in-line "Ratiomotor," has a double reduction drive. The unit can be disassembled if necessary into three unit parts for inspection or installation. These three units are made up of the motor and motor pinion, the center housing with a



driven internal and a driving spur gear mounted on one shaft, and the output end shield and shaft with a driven internal gear. Precision anti-friction bearings carry all radial and thrust loads. Available with output speeds of 108, 144, 172, 230 and 276 r.p.m. Equipped with a $\frac{1}{2}$ hp. or a $\frac{3}{4}$ hp. motor. Boston Gear Works, Inc., North Quincy, Mass.

Zirconium-Copper

Zirconium-copper, a new material for improving standard brasses and bronzes, is now available in the form of a concentrate. Two standard concentrations, containing 12½ per cent and 35 per cent zirconium are supplied. They are produced by the Hydrimet process which insures high purity. Zirconium not only acts as a deoxidizer and scavenger of a melt, but when alloyed with manganese bronzes, aluminum bronzes and others, it gives increased hardness and tensile strength, higher thermal and electrical conductivity, and improved corrosion resistance. Fine grain materials with clean grain boundaries result from its use. The concentration will alloy immediately and without difficulty with a melt. P. R. Mallory & Co., Inc., Indianapolis, Ind.

Books and Bulletins

Patents and the Public Interest

H. A. TOULMIN, JR.—*22 illustrations, 201 pages, 6x8¾ in. Blue clothboard covers. Published by Harper & Bros., 49 East 33rd St., New York, N. Y. Price $2.50.*

Col. H. A. Toulmin, Jr., well known to *Product Engineering* readers through his current articles on patent law, presents in this book a penetrating factual study of the patent system. Beginning by tracing its reasons for existence and economic background, the author goes on to discuss patents and public problems, dealing with patent pools, monopolies and suppression, and the effect of invention on labor, the farmer, and the general public.

Of particular significance in the light of recent agitation for reorganization of the patent system in Washington, the book analyzes the various proposals for reform. In the final section of the book, the author reviews recent contributions of the "tomorrow mind," and the effect of these developments on the public.

The author states: "This book is not a defense of the patent system nor a muck-raking expedition into its troubles. It is, I hope, a fair survey of the good in it, the bad that ought to be out of it, and the suggested lines of a reasoned revision of the system. Time and tides move on, and no system of laws of men such as this can ignore the changes dictated by the public interest."

Throughout his entire presentation, Mr. Toulmin adopts a fair and intellectual attitude, arriving at the general conclusion that the patent system, despite its recognized difficulties, has been and will continue to be a tremendous power in stimulating the inventive effort by which the American standard of living is raised.

Refrigerating Data Book and Catalog

Fourth edition. 527 pages, 6½ x 9¼ in. Clothboard covers. Published by the American Society of Refrigerating Engineers, 37 West 39th St., New York, N. Y. Price $4.

Previous editions of this data book have appeared in 1932, 1934 and 1936. This new volume is edited and labeled as Volume I, "Refrigerating Principles and Machinery," with revisions scheduled every four years. It will be followed in 1941 by Volume II, a data book on refrigeration applications. The greater part of the material appearing in the book is new, but the style of presentation conforms with previous issues. New material includes discussion of compression systems, fluid flow, refrigerant properties and tables, insulation problems, cork, conductivity tables and surface coolers. A food properties section, a section on domestic and commercial refrigerating machinery, and a section on controls have been added. The book is conveniently thumb-tabbed and indexed.

Engineering Opportunities

R. W. CLYNE, EDITOR—*397 pages, 5½x8¼ in. Clothboard covers. Published by D. Appleton-Century Co., 35 West 32nd St., New York, N. Y. Price $3.*

Edited for the man who contemplates entering the engineering field, or the engineering student who needs guidance in choosing the particular field in which to apply his technical training, this book contains 26 essays giving a bird's-eye view of industrial engineering today.

The various authors are experts in their individual fields. In writing about each industry, they cover briefly the background, present status and possibilities for the future. Engineering industries described include aluminum, automotive, aviation, metallurgy, glass, photography, plastics, rubber and steel.

Machine Design

STANTON E. WINSTON—*145 illustrations, 26 tables, 333 pages, 5½x8¼ in. Waterproof clothboard covers. Published by the American Technical Society, Drexel Ave. at 58th St., Chicago, Ill. Price $3.*

This new book should be of particular value as a beginning text in machinery design. The author has selected for his text, material that is basic to machine design in general, bringing out in its treatment the general ideas of engineering analysis which are fundamental to the entire field of design. The material is presented as simply and clearly as possible, by means of many examples which illustrate the method of analysis and sequence of thought required in solving design problems. The calculus is avoided; the only mathematics required is trigonometry and logarithms. For this reason, several rational formulas are included for which no derivations are given.

The subjects covered include: principles of simple and compound stresses; bolts and screws; cylinders and riveted joints, shafting and keys; couplings and clutches; pulleys, sheaves; friction and gear drives.

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Engineering Properties of Gray Cast Iron

56 pages, 7¾x11 in. Published by the Gray Iron Founders' Society, Inc., 1010 Public Square Bldg., Cleveland, Ohio.

This book is a carefully prepared critical summary of the vast amount of information available on gray cast iron. In the first part of the book reliable data on the common mechanical properties have been collected and are presented in tabular form. This is followed by a discussion of the effects of section size on the mechanical properties. Those additional properties of the material which cannot be expressed in terms of simple tests or listed numerically are discussed in the next part of the book. The book contains a section of comment on the inter-relation of the properties of gray cast iron. Several pages of literature reference, grouped by topics, complete the presentation.

Simple Blueprint Reading With Particular Reference to Welding

142 pages, 8½x11 in. Blue imitation leather covers. Published by the Lincoln Electric Co., 12,818 Coit Road, Cleveland, Ohio. Price 50 cents.

Compiled primarily for welders, this mimeographed book contains information of value to engineers working with mechanical design and construction. A comprehensive explanation gives the reader a clear understanding of symbols used in drawings of different types of welded joints. The 85 illustrations interspersed with the text offer many practical examples. Throughout, the book is presented in a manner to facilitate a quick grasp of the subject and to provide easy reference.

Practice in Machining Zinc Alloy Die Castings

18 illustrations, 24 pages, 8½x11 in. Published by The New Jersey Zinc Co., 160 Front St., New York, N. Y.

This booklet fills a long-felt need in offering an accurate and comprehensive discussion of the machining of zinc alloy die castings. After dealing with general considerations, the book covers the types of tools, tool grinding, speeds and feeds, and lubricants necessary for drilling, tapping, threading, reaming, facing, turning, milling, broaching and shaving, grinding and polishing, buffing, punching, and all other machining operations. Liberal use of illustrations supplements the text.

Every method reviewed in this publication is in actual commercial use, and is the recommendation of some die caster, some large user of die castings, or some tool manufacturer.

Manufacturers' Publications

ADJUSTABLE-SPEED DRIVE—Reliance Electric & Engineering Co., Ivanhoe Rd., Cleveland, Ohio. Bulletin 307, 6 pages, 8½x11 in. The new Reliance Type VS drive for small units of 1 hp. and up is described and illustrated in this bulletin.

AIR COMPRESSORS—Schramm, Inc., West Chester, Pa. Sales data book, 9¾x12 in., blue leatherette binding. The complete Schramm line of portable and stationary compressors, pneumatic tools, and miscellaneous compressors are described and illustrated in this well-presented catalog.

BAKELITE—Synthane Corp., Oaks, Pa. Instructions for machining Bakelite-laminated are given in the form of a condensed chart suitable for hanging on the wall. Of additional interest is a brief comparison of the circumstances under which the material should be machined by the purchaser or prefabricated.

BALL BEARING—Bearing Div., Stephens-Adamson Mfg. Co., Aurora, Ill. Catalog 739, 8 pages, 8½x11 in. Describes and illustrates the line of SealMaster ball bearing pillow blocks, flange units, and take-up units. Dimensions and load capacity tables are included.

CAPACITOR MOTORS—General Electric Co., Schenectady, N. Y. Bulletin GEA-2420, 4 pages, 8½x11 in. Type KC capacitor motors of ⅛ to ¾ hp. and 1,725 r.p.m., and ¼ to 1 hp. and 3,450 r.p.m., single phase, 60 cycle, are illustrated and described in this bulletin.

CAPACITOR MOTORS—Westinghouse Electric & Mfg. Co., East Pittsburgh, Pa. Bulletin F8485, 8½x11 in. This booklet shows cutaway drawings, outline dimensions and typical installations of capacitor motors of 1/20 to ¾ hp. for unit heater, fan and blower applications.

CHAIN DRIVE—Morse Chain Co., Ithaca, N. Y. Bulletin 75, 12 pages, 8½x11 in. Specification tables and capacity curves for the new Morse Round Pin Roller Chain are given in this well illustrated booklet, which also covers Morse clutches and Morse flexible couplings and universal drives.

CLUTCHES—Conway Clutch Co., 1503 Queen City Ave., Cincinnati, Ohio. Bulletin L28, 8 pages, 8½x11 in., Conway large size disc clutches. Bulletin XYZ-L, 4 pages, 8½x11 in., Conway sleeve clutches. Catalog P-24, 16 pages, 8½x11 in., Conway disc clutches. Bulletin 36, 8 pages, 8½x11 in., Conway compression clutches. Bulletin K-32, 4 pages, 8½x11 in., Conway one-revolution clutch and cam knockout type.

CLUTCHES—Carlyle Johnson Machine Co., Manchester, Conn. Catalog 1939, 10 pages, 6x9¼ in. Describes Johnson friction clutches with metal-to-metal friction, as well as the Super-Johnson type with Raybestos faced expansion ring. Includes complete dimension charts and tables.

COLLOIDAL GRAPHITE—Acheson Colloids Corp., Port Huron, Mich. Bulletin 102B, 4 pages, 8½x11 in. Method of lubrication of devices lacking continuous oil supply are covered in this bulletin, which also includes special formulas and treatment for dry lubrication of rubber and wood.

MAGNET WIRE—Anaconda Wire & Cable Co., 25 Broadway, New York, N. Y. Catalog C-352, second edition, 92 pages, 8½x11 in. Information on electrical and physical properties of magnet wire is given in this well presented catalog which contains many pages of tabular and technical data. Much space is also given to the use of magnet wire coils.

MOTORS—Allis-Chalmers Mfg. Co., Milwaukee, Wis. Bulletin B-6010, 8 pages, 8½x11 in. Illustrates, describes, and lists prices for squirrel cage and direct current motors. The common types of squirrel cage motors and their applications are listed in tabular form.

MOTOR SWITCH—Trumbull Electric Mfg. Co., Plainville, Conn. Bulletin, 4 pages, 8½x11 in. Trumbull type "TT" manual motor starters are covered in this bulletin. Features of operation in construction, applications and dimensional data and suggested specifications are set forth.

NICKEL ALLOYS—International Nickel Co., Inc., 67 Wall St., New York, N. Y. "Tremendous Trifles," 16 pages, 8½x11 in. Technical and mechanical data on nickel, Monel, Inconel, "Z" nickel, "K" Monel, and other high nickel alloys are presented with illustrations and charts in this booklet.

OIL GAGE PLUGS—Gits Bros. Mfg. Co., 1846-62 So. Kilbourn Ave., Chicago, Ill. Bulletin, 6x9 in. Illustrates and describes Gits brass gear case oil gage plugs, styles BW Hex, and CW Flanged.

PHILLIPS SCREWS—Pheoll Mfg. Co., 5700 Roosevelt Road, Chicago, Ill. Pamphlet 639, 4 pages, 8½x11 in. Describes the Pheoll-Phillips recessed head screws and bolts which have recently been added to the complete line of Pheoll fastenings. Illustrations show the advantages and applications.

PRECISION SPRINGS—Instrument Specialties Co., Inc., Little Falls, N. J. Bulletin describes precision springs made from beryllium copper and other precipitation-hardened alloys. The new precision technique of electronically measuring springs, and available production facilities are also covered.

PYROMETER—C. J. Tagliabue Mfg. Co., Park and Nostrand Aves., Brooklyn, N. Y. Catalog 1101E, 34 pages, 8½x11 in. The complete line of Celectray electric pyrometers, thermometers, photoelectrically balanced recorders, indicators, controllers and recording controllers are listed and described in this well illustrated catalog.

RECTIFIERS—Hanson-Van Winkle-Munning Co., Matawan, N. J. Bulletin ER-102. Complete detailed treatise on copper-oxide rectification equipment for producing low voltage, direct current, for electrodeposition.

ROLLER BEARINGS—SKF Industries, Inc., Front St. and Erie Ave., Philadelphia, Pa. Bulletin 250-5S-7-39, 32 pages, 8½x11 in. The application of SKF double row cylindrical roller bearings in machine tool spindles is discussed in this booklet. Many typical mountings on various types of machine spindles are diagrammatically described.

RUBBER—Manhattan Rubber Mfg. Div., 94 Townsend St., Passaic, N. J. "Manhattan Rubber Products for Industry." Condensed catalog of mechanical rubber goods describes many products manufactured by Manhattan, including belting, hose, packing, molded rubber goods, industrial asbestos friction material, rubber roll coverings, tank linings, and abrasive wheels.

SOLENOIDS—General Electric Co., Schenectady, N. Y. Bulletin GEA-2080, 2 pages, 8½x11 in. Describes and illustrates a.c. and d.c. solenoids, Type CR9503, for general industrial applications.

STAINLESS STEEL—Atlas Stainless Steel Castings, Div. of Atlas Foundry Co., Irvington, N. J. "Castings of Stainless Steel," 12x9 in. Sets forth desired characteristics of stainless steel castings and includes an extensive list of the many uses of this metal.

SWITCHGEAR—Allis-Chalmers Mfg. Co., Milwaukee, Wis. Bulletin B-6012, 12 pages, 8½x11 in. Illustrates, describes and gives dimensions for Metal-clad vertical lift switchgear. Bulletin B-6011, 12 pages, 8½x11 in. The Allis-Chalmers Indoor Cubicle Type of switchgear is covered in this bulletin.

THERMO-MAGNETIC RELAYS—Roller-Smith Co., 1766 West Market St., Bethlehem, Pa. Catalog 12-A, 8 pages, 8½x11 in. This bulletin illustrates, describes and gives wiring diagrams for the Type DT-1 thermo-magnetic relays designed especially for motor, generator, and transformer protection.

THERMOCOUPLES—The Foxboro Co., Foxboro, Mass. Bulletin 2350, 36 pages. Thermocouples, thermocouple assemblies, and parts made by Foxboro are illustrated and described in this bulletin, which gives detailed specifications for various types and full information as to the temperature ranges.

TRANSFORMERS—Dongan Electric Mfg. Co., Detroit, Mich. Bulletin N-639-1, 8½x11 in. Describes the advantages and features of a new line of streamlined 1940 luminous tube transformers.

VALVES—Jenkins Bros., 80 White St., New York, N. Y. Form 183, 24 pages, 3½x6¼ in. This booklet is a photographic study of all types of iron valves, analyzing the factors of valve life and maintenance. The booklet includes a handy reference chart giving types, sizes and figure numbers for ordering Jenkins 125 lb. iron valves.

WIRING DEVICES—Harvey Hubbell, Inc., Bridgeport, Conn. Catalog 24, 82 pages, 8½x10¾ in. This complete catalog covers the line of Hubbell Rugged wiring devices with lists of specifications and prices.

Helical Spring Tables—II

PAUL KLAMP

WHEREAS the specification of helical compression springs usually calls for long, tedious calculations, this article presents a short-cut method whereby a spring for general purposes is "selected" from a table. The first part of this article, presented on pages 361–364 of the August number of *Product Engineering*, covered the general considerations of this quick method. Table A, containing data for the choice of the proper stress group, was given and discussed. The first page of Table B, covering springs from $\frac{3}{16}$ in. to $\frac{1}{2}$ in. in outside diameter, was included with complete derivations of table values and discussions of terms used. In the October number the proper procedures for the selection of the six general types of springs will be presented in a manner which can readily be made into mimeographed or printed forms for use in cases where specification of a large number of springs is required.

Total Deflection from Table C

Usually, the following conditions are prevailing when a helical compression spring operates with a reciprocating motion: The working stroke or range is only a certain part of the total deflection, and the load at the maximum working length is the basic load. So the total deflection involves three stages. First, the free length without load; second, the maximum working length (assembled length) with the required load; and third, the minimum working length with an increased load. The choice of the load increase during the working stroke depends on the operating conditions. Therefore, it is preferable to base the spring design on a predetermined load increase, whereas in present spring calculations this load increase and, therefore, the stress range which is definitely related to it, usually are found afterwards, and that is one of the reasons why different outside diameters and wire sizes must be considered before a suitable spring is determined.

But, with the working stroke given and a definite value chosen for the load increase during the stroke, it is possible to predetermine the load at the minimum working length and the total deflection, before selecting a certain size spring. Letting

P_1 = load at maximum working length
P_2 = load at minimum working length
i = load increase factor = $P_2 \div P_1$
s = working stroke
D = total deflection

Then
$$P_2 = P_1 i \qquad (13)$$
and, since the load increases in direct proportion to the deflection,
$$\frac{P_2}{D} = \frac{P_2 - P_1}{s}$$
But
$$P_2 = P_1 i$$
So
$$\frac{P_1 i}{D} = \frac{P_1 i - P_1}{s}$$

Dividing both sides of the equation by P_1, it is found that
$$\frac{i}{D} = \frac{i - 1}{s}$$

Solving for D, we have
$$D = \frac{si}{i - 1} \qquad (14)$$

Therefore, when P_1, i and s are given in the spring requirements, P_2 and D are obtained from Equations (13) and (14). The values of D for various strokes s and load increase factors i are given on Table C. Thus, the load at the minimum working length and the total deflection are found with a minimum of effort, as per directions in the spring selection forms to follow. For values i or s not shown on Table C, the total deflection D is found according to the formula on the bottom of the table.

Length of Inactive Coils

The combined space occupied by the inactive coils at both ends may be taken as follows:

Squared and ground ends — 2 × wire diameter

Squared ends, not ground — 3 × wire diameter

Open ends, ground or not ground — allow space equal to wire diameter.

Squared and ground ends are used most frequently. Squared ends which are not ground are preferable for thin wire, especially when the spring index (relation between mean coil diam. and wire size) is large. Open ends, either ground or not ground, are sometimes used when the length of the spring must be held down to a minimum, but these springs get easily tangled in handling.

Materials

The stress group Table A shows a number of spring wire materials, as well as the stress groups recommended for the various materials and for different types of loading and different load increase factors i. Since the stresses used in Table B are limited to three values for each wire size, the stresses according to Table A compare only approximately with modern stress recommendations and are usually somewhat on the conservative side. But for the general run of springs, the choice of stresses is quite sufficient. In the following are a few notes on the individual materials. The first three of these are more common for general purpose springs than the remaining ones and are separated by a double-line on Table A.

MUSIC WIRE is used for wire diameters up to 0.080 in. and sometimes larger sizes. They are drawn to a different gage system than the standard Washburn and Moen sizes. But the W.&M. sizes given in Table B can be matched, within 0.001 in. with W.&M. music wire sizes. Therefore, in order to simplify Table B, all sizes are standard W.&M. To avoid confusion, it is preferable to specify wire sizes in decimal inches.

PRETEMPERED CARBON STEEL WIRE is very common for the medium sizes. Heat treatment (blueing) after coiling is usually preferable so as to eliminate stresses set up in coiling.

HOT ROLLED CARBON STEEL WIRE is used for larger sizes. Should be quenched and tempered after coiling. Sizes over $\frac{1}{2}$ in. show a noticeable decarburization of the surface and a consequent drop in the torsional modulus. To compensate for this, reduce the table load for sizes over $\frac{1}{2}$ in. by 10 per cent, but leave the ratio R unchanged.

HARD DRAWN CARBON STEEL WIRE comes in medium sizes. Price is lower,

but this wire is not suitable for severe service.

HIGH GRADE VALVE SPRING WIRE for springs of medium wire sizes. High endurance limit makes this material suitable for severest service. Should be heat treated (blued) after coiling so as to remove stresses due to coiling. Suitable for operation at temperatures up to about 350 deg. F.

STAINLESS STEEL WIRE resists corrosion and is suitable for higher temperatures of around 500 to 600 deg. F. Stainless steel has a lower torsional modulus. Therefore, the table loads should be reduced by 10 per cent, but the ratio R as shown in Table B should be maintained for this material.

CHROME-VANADIUM-STEEL WIRE used for springs of medium and larger wire sizes. Has better fatigue resistance than straight carbon steel. Suitable to operate at temperatures up to about 400 deg. F. To be quenched and tempered after coiling.

NON-FERROUS SPRING WIRE materials are not included in Table A, because they are not drawn to Washburn & Moen sizes and thus cannot be selected from Table B.

Table C—Values for Total Reflection, *D*

Working Stroke In.	LOAD INCREASE FACTOR, *i*															
	1.2		1.25		1.333		1.4		1.5		1.667		1.8		2	
	Frac.	Dec.	Frac.	Dec.	Frac.	Dec.	Frac.	Dec.	Frac.	Dec.	Frac.	Dec.	Frac.	Dec.	Frac.	Dec.
1/32	3/16	0.188	5/32	0.156	1/8	0.125	7/64	0.109								
3/64	9/32	0.281	15/64	0.234	3/16	0.188		0.164	9/64	0.141						
1/16	3/8	0.375	5/16	0.313	1/4	0.250	7/32	0.219	3/16	0.188	5/32	0.156	9/64	0.141	1/8	0.125
5/64	15/32	0.469	25/64	0.391	5/16	0.313		0.273	15/64	0.234		0.195		0.176	5/32	0.156
3/32	9/16	0.563	15/32	0.469	3/8	0.375	21/64	0.328	9/32	0.281	15/64	0.234		0.211	3/16	0.188
7/64	21/32	0.656	35/64	0.547	7/16	0.438		0.383	21/64	0.328		0.273		0.246	7/32	0.219
1/8	3/4	0.750	5/8	0.625	1/2	0.500	7/16	0.438	3/8	0.375	5/16	0.313	9/32	0.281	1/4	0.250
5/32	15/16	0.938	25/32	0.781	5/8	0.625	35/64	0.547	15/32	0.469	25/64	0.391		0.352	5/16	0.313
3/16	1 1/8	1.125	15/16	0.938	3/4	0.750	21/32	0.656	9/16	0.563	15/32	0.469	27/64	0.422	3/8	0.375
7/32	1 5/16	1.313	1 3/32	1.094	7/8	0.875	49/64	0.766	21/32	0.656	35/64	0.547		0.492	7/16	0.438
1/4	1 1/2	1.500	1 1/4	1.250	1		1.000	7/8	0.875	3/4	0.750	5/8	0.625	9/16	0.563	1/2	0.500
9/32	1 11/16	1.688	1 13/32	1.406	1 1/8		1.125	63/64	0.984	27/32	0.844	45/64	0.703		0.633	9/16	0.563
5/16	1 7/8	1.875	1 9/16	1.563	1 1/4		1.250	1 3/32	1.094	15/16	0.938	25/32	0.781	45/64	0.703	5/8	0.625
11/32	2 1/16	2.063	1 23/32	1.719	1 3/8		1.375	1 13/64	1.203	1 1/32	1.031	55/64	0.859		0.773	11/16	0.688
3/8	2 1/4	2.250	1 7/8	1.875	1 1/2		1.500	1 5/16	1.313	1 1/8	1.125	15/16	0.938	27/32	0.844	3/4	0.750
13/32	2 7/16	2.438	2 1/32	2.031	1 5/8		1.625	1 27/64	1.422	1 7/32	1.219	1 1/64	1.016		0.914	13/16	0.813
7/16	2 5/8	2.625	2 3/16	2.188	1 3/4		1.750	1 17/32	1.531	1 5/16	1.313	1 3/32	1.091	63/64	0.984	7/8	0.875
15/32	2 13/16	2.813	2 11/32	2.344	1 7/8		1.875	1 41/64	1.641	1 13/32	1.406	1 11/64	1.172		1.051	15/16	0.938
1/2	3		3.000	2 1/2		2.500	2		2.000	1 3/4	1.750	1 1/2	1.500	1 1/4	1.250	1 1/8	1.125	1		1.000
9/16	3 3/8		3.375	2 13/16		2.813	2 1/4		2.250	1 31/32	1.969	1 11/16	1.688	1 13/32	1.406	1 17/64	1.266	1 1/8		1.125
5/8	3 3/4		3.750	3 1/8		3.125	2 1/2		2.500	2 3/16	2.188	1 7/8	1.875	1 9/16	1.563	1 13/32	1.406	1 1/4		1.250
11/16	4 1/8		4.125	3 7/16		3.438	2 3/4		2.750	2 13/32	2.406	2 1/16	2.063	1 23/32	1.719	1 35/64	1.547	1 3/8		1.375
3/4	4 1/2		4.500	3 3/4		3.750	3		3.000	2 5/8	2.625	2 1/4	2.250	1 7/8	1.875	1 11/16	1.688	1 1/2		1.500
13/16	4 7/8		4.875	4 1/16		4.063	3 1/4		3.250	2 27/32	2.844	2 7/16	2.438	2 1/32	2.031	1 53/64	1.828	1 5/8		1.625
7/8	5 1/4		5.250	4 3/8		4.375	3 1/2		3.500	3 1/16	3.063	2 5/8	2.625	2 3/16	2.188	1 31/32	1.969	1 3/4		1.750
15/16	5 5/8		5.625	4 11/16		4.688	3 3/4		3.750	3 9/32	3.281	2 13/16	2.813	2 11/32	2.344	2 7/64	2.119	1 7/8		1.875
1	6		6.000	5		5.000	4		4.000	3 1/2	3.500	3		3.000	2 1/2	2.500	2 1/4	2.250	2		2.000
1 1/8	6 3/4		6.750	5 5/8		5.625	4 1/2		4.500	3 15/16	3.938	3 3/8		3.375	2 13/16	2.813	2 17/32	2.053	2 1/4		2.250
1 1/4	7 1/2		7.500	6 1/4		6.250	5		5.000	4 3/8	4.375	3 3/4		3.750	3 1/8	3.125	2 13/16	2.813	2 1/2		2.500
1 3/8	8 1/4		8.250	6 7/8		6.875	5 1/2		5.500	4 13/16	4.813	4 1/8		4.125	3 7/16	3.438	3 3/32	3.094	2 3/4		2.750
1 1/2	9		9.000	7 1/2		7.500	6		6.000	5 1/4	5.250	4 1/2		4.500	3 3/4	3.750	3 3/8	3.375	3		3.000
1 5/8	9 3/4		9.750	8 1/8		8.125	6 1/2		6.500	5 11/16	5.688	4 7/8		4.875	4 1/16	4.063	3 21/32	3.656	3 1/4		3.250
1 3/4				8 3/4		8.750	7		7.000	6 1/8	6.125	5 1/4		5.250	4 3/8	4.375	3 15/16	3.938	3 1/2		3.500
1 7/8				9 3/8		9.375	7 1/2		7.500	6 9/16	6.563	5 5/8		5.625	4 11/16	4.688	4 7/32	4.219	3 3/4		3.750
2				10		10.000	8		8.000	7	7.000	6		6.000	5	5.000	4 1/2	4.500	4		4.000
2 1/4							9		9.000	7 7/8	7.875	6 3/4		6.750	5 5/8	5.625	5 1/16	5.063	4 1/2		4.500
2 1/2							10		10.000	8 3/4	8.750	7 1/2		7.500	6 1/4	6.250	5 5/8	5.625	5		5.000
2 3/4										9 5/8	9.625	8 1/4		8.250	6 7/8	6.875	6 3/16	6.188	5 1/2		5.500
3												9		9.000	7 1/2	7.500	6 3/4	6.750	6		6.000
3 1/4												9 3/4		9.750	8 1/8	8.125	7 5/16	7.313	6 1/2		6.500
3 1/2															8 3/4	8.750	7 7/8	7.875	7		7.000
3 3/4															9 3/8	9.375	8 7/16	8.438	7 1/2		7.500
4															10	10.000	9	9.000	8		8.000
4 1/2																			9		9.000

$$D = \frac{is}{i - 1}$$

Table B—Selection of Springs

Continued from p. 364, August Number

Spring O. D. In.	Wire Dia. In.	Spring I. D. In.	Low Stress Group				Medium Stress Group				High Stress Group			
			Coils Per In.	Safe Load P Lb.	Spring Ratio R	Defl. Per Coil f In.	Coils Per In.	Safe Load P Lb.	Spring Ratio R	Defl. Per Coil f In.	Coils Per In.	Safe Load P Lb.	Spring Ratio R	Defl. Per Coil f In.
	.0348	.193	6	1.72	1.39	.120	5	2.15	1.34	.150	4	2.58	1.39	.180
	.041	.181	6	2.80	1.71	.0978	5½	3.50	1.49	.122	5	4.20	1.36	.147
	.0475	.168	7	4.33	1.77	.0808	6	5.41	1.65	.101	5½	6.49	1.50	.121
	.054	.155	7	6.32	2.10	.0680	6	7.90	1.96	.0850	6	9.48	1.63	.102
9/16	.0625	.138	8	9.72	2.26	.0554	7	12.2	2.06	.0692	6	11.6	2.01	.0831
	.072	.119	8	14.7	2.73	.0449	7	18.4	2.54	.0562	6	22.1	2.47	.0674
	.080	.103	8	20.0	3.28	.0381	7	25.0	3.00	.0477	6	30.0	2.92	.0572
	.0915	.380	7	29.5	1.66	.0306	7	36.8	3.74	.0382	6	44.2	3.64	.0458
	3/32	.375	7	31.6	4.88	.0293	7	39.5	3.90	.0366	6	47.4	3.79	.0440
	.1055	.352	7	40.6	6.57	.0218	7	49.8	5.35	.0267	6	59.8	5.20	.0320
	.041	.543	5½	2.53	1.47	.124	4½	3.16	1.43	.155	4	3.79	1.35	.186
	.0475	.530	6	3.91	1.62	.103	5	4.88	1.55	.129	4½	5.85	1.44	.155
	.054	.517	6	5.72	1.91	.0871	5½	7.15	1.67	.109	5	8.58	1.53	.131
	.0625	.500	7	8.80	2.00	.0714	6	11.0	1.87	.0893	5½	13.2	1.70	.107
	.072	.481	7	13.3	2.45	.0584	6	16.7	2.28	.0730	5½	20.0	2.08	.0876
5/8	.080	.465	7	18.2	2.86	.0499	6	22.7	2.67	.0624	6	27.2	2.23	.0749
	.0915	.442	7	26.8	3.53	.0405	6	33.5	3.30	.0506	6	40.2	2.75	.0607
	3/32	.438	7	28.8	3.68	.0389	6	36.0	3.43	.0486	6	43.2	2.86	.0583
	.1055	.414	7	37.1	4.89	.0292	6	45.5	4.65	.0359	6	54.6	3.87	.0430
	.1205	.384	6	54.2	7.26	.0230	6	66.5	5.92	.0282	6	79.8	4.93	.0338
	1/8	.375	6	60.1	7.79	.0214	6	73.8	6.35	.0263	6	88.5	5.29	.0315
	.041	.606	4½	2.31	1.45	.153	4	2.88	1.31	.192	3¼	3.46	1.34	.230
	.0475	.593	5	3.57	1.57	.128	4½	4.46	1.39	.160	3½	5.35	1.49	.192
	.054	.580	5½	5.22	1.67	.109	4½	6.53	1.64	.136	4	7.83	1.54	.163
	.0625	.563	6	8.01	1.86	.0895	5	10.1	1.79	.112	4½	12.1	1.66	.134
	.072	.544	6	12.2	2.26	.0737	5½	15.3	1.98	.0921	5	18.3	1.81	.111
11/16	.080	.528	6	16.6	2.63	.0633	6	20.8	2.11	.0791	5	24.9	2.11	.0949
	.0915	.505	6	24.6	3.22	.0517	6	30.8	2.58	.0647	5½	36.9	2.34	.0776
	3/32	.500	6	26.4	3.35	.0498	6	33.0	2.68	.0622	5½	39.6	2.43	.0747
	.1055	.477	6	34.1	4.42	.0378	6	41.9	3.60	.0463	5½	50.2	3.27	.0556
	.1205	.447	6	50.0	5.54	.0301	6	61.4	4.52	.0369	5½	73.6	4.11	.0443
	1/8	.438	6	55.5	5.92	.0282	5½	68.1	5.26	.0316	5½	81.8	4.39	.0415
	.135	.418	5½	69.1	7.45	.0244	5½	84.7	6.07	.0299	5½	102	5.06	.0359
	.0475	.655	4½	3.28	1.43	.155	3½	4.10	1.47	.194	3¼	4.92	1.32	.233
	.054	.642	5	4.80	1.51	.132	4	6.00	1.51	.165	3½	7.20	1.44	.199
	.0625	.625	5½	7.40	1.66	.110	4½	9.25	1.62	.137	4	11.1	1.52	.164
	.072	.606	5½	11.2	2.01	.0907	5	14.1	1.76	.113	4½	16.9	1.63	.136
	.080	.590	6	15.3	2.13	.0783	5	19.2	2.04	.0978	4½	23.0	1.90	.117
3/4	.0915	.567	6	22.7	2.59	.0644	5½	28.4	2.26	.0805	5	34.1	2.07	.0965
	3/32	.563	6	24.4	2.69	.0621	5½	30.5	2.34	.0776	5	36.6	2.15	.0931
	.1055	.539	6	31.5	3.52	.0474	5½	38.7	3.13	.0582	5	46.4	2.87	.0698
	.1205	.509	5½	46.3	4.77	.0381	5½	56.9	3.89	.0468	5	68.2	3.56	.0561
	1/8	.500	5½	51.4	5.08	.0358	5½	63.1	4.14	.0439	5	75.8	3.80	.0527
	.135	.480	5½	64.2	5.81	.0313	5	78.8	5.21	.0384	5	94.5	4.34	.0461
	.1483	.453	5	83.8	7.62	.0263	5	103	6.21	.0322	5	123	5.17	.0387
	.054	.767	3½	4.14	1.53	.187	3¼	5.17	1.32	.234	2¾	6.20	1.30	.281
	.0625	.750	4	6.38	1.60	.156	3½	7.97	1.47	.195	3	9.57	1.43	.234
	.072	.731	4½	9.70	1.71	.130	4	12.1	1.54	.163	3½	14.6	1.47	.195
	.080	.715	4½	13.2	1.97	.113	4	16.6	1.77	.141	3½	19.9	1.69	.170
	.0915	.692	5	19.7	2.13	.0939	4½	24.6	1.89	.117	4	29.5	1.78	.141
	3/32	.688	5	21.1	2.20	.0907	4½	26.4	1.96	.113	4	31.6	1.84	.136
7/8	.1055	.661	5	27.4	2.85	.0701	5	33.6	2.33	.0860	4½	40.4	2.15	.103
	.1205	.634	5	40.4	3.50	.0572	5	49.5	2.85	.0702	4½	59.4	2.64	.0842
	1/8	.625	5	44.9	3.71	.0540	4½	55.1	3.36	.0662	4½	66.1	2.80	.0795
	.135	.605	5	56.2	4.20	.0477	4½	68.9	3.80	.0585	4½	82.7	3.17	.0702
	.1483	.578	5	73.6	4.93	.0406	4½	90.3	4.46	.0498	4½	108	3.72	.0598
	5/32	.563	4½	85.6	6.01	.0370	4½	105	4.89	.0454	4	126	4.59	.0545
	.162	.551	4½	94.6	6.41	.0346	4½	116	5.24	.0424	4	139	4.91	.0509
	.177	.521	4½	122	7.58	.0293	4	149	6.95	.0360	4	179	5.79	.0432

Table B—Selection of Springs

Spring O. D. In.	Wire Dia. In.	Spring I. D. In.	Low Stress Group				Medium Stress Group				High Stress Group			
			Coils Per In.	Safe Load P Lb.	Spring Ratio R	Defl. Per Coil f In.	Coils Per In.	Safe Load P Lb.	Spring Ratio R	Defl. Per Coil f In.	Coils Per In.	Safe Load P Lb.	Spring Ratio R	Defl. Per Coil f In.
1	.0625	0.875	3¼	5.60	1.46	.211	2¾	7.00	1.38	.263	2¼	8.41	1.41	.316
	.072	0.856	3½	8.53	1.62	.177	3	10.7	1.51	.221	2¾	12.8	1.37	.265
	.080	0.840	4	11.7	1.62	.154	3¼	14.6	1.60	.192	3	17.5	1.44	.231
	.0915	0.817	4	17.3	1.94	.129	3½	21.7	1.77	.161	3¼	26.0	1.59	.194
	3/32	0.813	4	18.6	2.00	.125	3½	23.3	1.83	.156	3¼	27.9	1.64	.187
	.1055	0.789	4½	24.2	2.29	.0972	4	29.7	2.10	.119	3½	35.6	2.00	.143
	.1205	0.759	4½	35.7	2.77	.0802	4	43.8	2.54	.0981	4	52.6	2.12	.118
	1/8	0.750	4½	39.8	2.93	.0759	4	48.8	2.69	.0931	4	58.5	2.24	.112
	.135	0.730	4½	49.7	3.30	.0674	4	61.1	3.02	.0828	4	73.3	2.52	.0993
	.1483	0.703	4½	65.4	3.83	.0581	4	80.2	3.51	.0713	4	96.3	2.92	.0856
	5/32	0.688	4½	76.1	4.17	.0533	4	93.4	3.82	.0651	4	112	3.19	.0784
	.162	0.676	4	84.4	4.99	.0501	4	104	4.06	.0615	3½	124	3.87	.0738
	.177	0.646	4	109	5.81	.0430	4	134	4.74	.0528	3½	160	4.51	.0633
	3/16	0.625	4	128	6.46	.0387	4	157	5.26	.0475	3½	189	5.01	.0570
	.192	0.616	4	137	6.75	.0370	3½	168	6.29	.0454	3½	202	5.21	.0545
1 1/8	.072	0.981	3	7.61	1.45	.230	2½	9.52	1.39	.288	2¼	11.4	1.29	.345
	.080	0.965	3¼	10.4	1.53	.202	2¾	13.0	1.41	.252	2¼	15.6	1.47	.303
	.0915	0.942	3½	15.5	1.68	.170	3	19.4	1.57	.212	2½	23.3	1.57	.255
	3/32	0.938	3½	16.7	1.74	.164	3	20.8	1.62	.206	2¾	25.0	1.47	.247
	.1055	0.914	4	21.6	1.94	.129	3½	26.5	1.81	.158	3	31.8	1.76	.189
	.1205	0.884	4	32.0	2.34	.107	3½	39.3	2.18	.131	3¼	47.1	1.95	.158
	1/8	0.875	4	35.6	2.46	.102	3½	43.7	2.29	.125	3¼	52.5	2.06	.150
	.135	0.855	4	44.7	2.76	.0908	3½	54.8	2.57	.111	3½	65.8	2.14	.134
	.1483	0.828	4	58.8	3.17	.0788	3½	72.1	2.96	.0967	3½	86.6	2.46	.116
	5/32	0.813	4	68.5	3.45	.0726	3½	84.1	3.21	.0891	3½	101	2.67	.107
	.162	0.801	4	75.9	3.65	.0685	3½	93.2	3.40	.0840	3½	112	2.83	.101
	.177	0.771	4	98.2	4.22	.0593	3½	121	3.93	.0728	3½	145	3.27	.0873
	3/16	0.750	3½	116	5.32	.0537	3½	142	4.33	.0659	3½	171	3.61	.0791
	.192	0.741	3½	124	5.54	.0516	3½	152	4.51	.0633	3½	183	3.76	.0759
	.207	0.711	3½	154	6.34	.0451	3½	189	5.16	.0553	3¼	227	4.64	.0664
	.2253	0.674	3½	195	7.44	.0384	3¼	240	6.53	.0472	3¼	288	5.44	.0566
1 1/4	.080	1.090	2¾	9.40	1.42	.256	2¼	11.5	1.39	.320	2	14.1	1.30	.384
	.0915	1.067	3	14.0	1.54	.216	2½	17.5	1.48	.270	2¼	21.0	1.37	.324
	3/32	1.063	3	15.1	1.59	.209	2½	18.8	1.53	.262	2¼	22.6	1.42	.314
	.1055	1.039	3½	19.6	1.74	.165	3	24.0	1.65	.202	2½	28.8	1.65	.242
	.1205	1.009	3½	28.9	2.08	.138	3¼	35.5	1.82	.169	2¾	42.6	1.79	.203
	1/8	1.000	3½	32.2	2.19	.131	3¼	39.5	1.92	.160	3	47.4	1.73	.192
	.135	0.980	3½	40.5	2.43	.118	3¼	49.7	2.13	.141	3	59.6	1.93	.173
	.1483	0.953	3½	53.3	2.79	.103	3½	65.4	2.27	.126	3	78.5	2.21	.151
	5/32	0.938	3½	62.1	3.01	.0948	3½	76.2	2.46	.116	3	91.5	2.39	.140
	.162	0.926	3½	69.0	3.18	.0898	3½	84.7	2.59	.110	3¼	102	2.33	.132
	.177	0.896	3½	89.4	3.65	.0783	3¼	110	3.20	.0960	3¼	132	2.67	.115
	3/16	0.875	3½	106	4.01	.0712	3¼	130	3.52	.0874	3¼	155	2.93	.105
	.192	0.866	3½	113	4.17	.0685	3¼	139	3.66	.0841	3¼	167	3.05	.101
	.207	0.836	3½	140	4.73	.0604	3¼	172	4.15	.0741	3	207	3.75	.0889
	.2253	0.799	3¼	179	5.93	.0519	3¼	219	4.83	.0637	3	263	4.36	.0764
	.2437	0.763	3¼	203	7.53	.0409	3	241	6.80	.0490	3	293	5.66	.0588
	1/4	0.750	3	219	8.57	.0389	3	262	7.14	.0467	3	315	5.95	.0560
1 3/8	.0915	1.192	2½	12.8	1.49	.268	2	16.0	1.49	.335	1¾	19.1	1.42	.402
	3/32	1.188	2½	13.7	1.54	.260	2¼	17.2	1.37	.325	1¾	20.6	1.47	.390
	.1055	1.164	3	17.9	1.63	.205	2½	21.9	1.59	.252	2¼	26.3	1.47	.302
	.1205	1.134	3¼	26.5	1.79	.172	2¾	32.5	1.72	.211	2½	39.0	1.58	.254
	1/8	1.125	3¼	29.5	1.88	.161	2¾	36.2	1.81	.201	2½	43.4	1.66	.242
	.135	1.105	3¼	37.0	2.08	.148	3	45.4	1.84	.181	2½	54.5	1.84	.218
	.1483	1.078	3¼	48.8	2.38	.130	3	59.9	2.10	.159	2¾	71.9	1.91	.191
	5/32	1.063	3¼	56.9	2.56	.120	3	69.8	2.26	.147	2¾	83.7	2.06	.177
	.162	1.051	3¼	63.2	2.70	.114	3	77.6	2.38	.140	2¾	93.1	2.17	.168
	.177	1.021	3¼	81.9	3.08	.0998	3	101	2.72	.123	2¾	121	2.47	.147
	3/16	1.000	3¼	96.8	3.37	.0913	3	119	2.98	.112	2¾	143	2.71	.134
	.192	0.991	3¼	101	3.50	.0880	3	127	3.09	.108	2¾	153	2.81	.130
	.207	0.961	3¼	129	3.95	.0779	3	158	3.49	.0956	2¾	190	3.17	.115
	.2253	0.924	3	165	4.93	.0676	3	202	4.02	.0830	2¾	243	3.65	.0996
	.2437	0.888	3	188	6.22	.0536	3	225	5.19	.0643	2¾	270	4.72	.0771
	1/4	0.875	3	202	6.51	.0512	3	242	5.43	.0611	2¾	291	4.93	.0737